PB80-197320

Carbon Adsorption Isotherms for Toxic Organics

(U.S.) Municipal Environmental Research Lab.
Cincinnati, OH

April 1980

U.S. Department of Commerce
National Technical Information Service
NTIS

United States
Environmental Protection
Agency

Municipal Environmental Research
Laboratory
Cincinnati OH 45268

EPA-600/8-80-023
April 1980

PB80-197320

Research and Development

EPA

Carbon Adsorption Isotherms for Toxic Organics

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

RESEARCH REPORTING SERIES

Research reports of the Office of Research and Development, U.S. Environmental Protection Agency, have been grouped into nine series. These nine broad categories were established to facilitate further development and application of environmental technology. Elimination of traditional grouping was consciously planned to foster technology transfer and a maximum interface in related fields. The nine series are:

1. Environmental Health Effects Research
2. Environmental Protection Technology
3. Ecological Research
4. Environmental Monitoring
5. Socioeconomic Environmental Studies
6. Scientific and Technical Assessment Reports (STAR)
7. Interagency Energy-Environment Research and Development
8. "Special" Reports
9. Miscellaneous Reports

This report has been assigned to the "SPECIAL" REPORTS series. This series is reserved for reports targeted to meet the technical information needs of specific user groups. The series includes problem-oriented reports, research application reports, and executive summary documents. Examples include state-of-the-art analyses, technology assessments, design manuals, user manuals, and reports on the results of major research and development efforts.

This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/8-80-023	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE CARBON ADSORPTION ISOTHERMS FOR TOXIC ORGANICS		5. REPORT DATE April 1980 (Issuing Date)
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Richard A. Dobbs, Jesse M. Cohen		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Wastewater Research Division, TPDB, P-CTS Municipal Environmental Research Laboratory U.S. Environmental Protection Agency Cincinnati, Ohio 45268		10. PROGRAM ELEMENT NO. 36B1C AI-02
		11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Municipal Environmental Research Laboratory-Cin.,OH Office of Research and Development U.S.Environmental Protection Agency Cincinnati, Ohio 45268		13. TYPE OF REPORT AND PERIOD COVERED Research 8/72 - 3/1980
		14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES

Contact: Richard A. Dobbs (513) 684-7649

16. ABSTRACT

An experimental protocol for measuring the activated carbon adsorption isotherm was developed and applied to a wide range of organic compounds. Methods for treatment of the isotherm data and a standard format for presentation of results are shown. In the early phase of the study selection of compounds for testing in the experimental program presented a formidable task. Initial selections were based on the following criteria: (1) annual quantity produced, (2) critical concentration required to produce an adverse environmental effect, (3) probability of occurrence in water or wastewater, (4) persistence in the water environment, and (5) solubility. During the course of the study the Occupational Safety and Health Administration's (OSHA) list of regulated carcinogens and the U.S. Environmental Protection Agency's Consent Decree list of priority pollutants were developed. These compounds were added to those previously selected for the experimental phase of the study.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Activated Carbon Treatment Adsorption	Physical-Chemical Treatment	13B

18. DISTRIBUTION STATEMENT Release to Public	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 332
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

☆ U.S. GOVERNMENT PRINTING OFFICE: 1980 -657-146/5645

EPA-600/8-80-023
April 1980

CARBON ADSORPTION ISOTHERMS FOR TOXIC ORGANICS

by

Richard A. Dobbs
Jesse M. Cohen
Wastewater Research Division
Municipal Environmental Research Laboratory
Cincinnati, Ohio 45268

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

DISCLAIMER

This report has been reviewed by the Municipal Environmental Research Laboratory, U.S. Environmental Protection Agency, and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution, and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This laboratory has had a continuing interest in the adsorption of organic compounds on activated carbon. During the past several years adsorption data have been determined for compounds for which little or no data are available in the literature.

The recent interest in toxic substances and their treatability by carbon has created a need for this kind of information. To meet this demand data from this laboratory have been collected under one cover. A second purpose of this report is to encourage some uniformity in the testing protocol and handling of data so that adsorbability data can be compared among compounds.

Francis T. Mayo
Director
Municipal Environmental Research
Laboratory

ABSTRACT

This research program was initiated with the overall objective of determining the capability of activated carbon to sorb priority pollutants and other hazardous organic compounds from aqueous solution.

An experimental protocol for measuring the activated carbon adsorption isotherm was developed and applied to a wide range of organic compounds. Methods for treatment of the isotherm data and a standard format for presentation of results are presented. In the early phase of the study selection of compounds for testing in the experimental program presented a formidable task. Initial selections were based on the following criteria: (1) annual quantity produced, (2) critical concentration required to produce an adverse environmental effect, (3) probability of occurrence in water or wastewater, (4) persistence in the water environment, and (5) solubility. During the course of the study the Occupational Safety and Health Admintration's (OSHA) list of regulated carcinogens and the U.S. Environmental Protection Agency's Consent Decree list of priority pollutants were developed. These compounds were added to those previously selected for the experimental phase of the study.

This report covers a period from August 8, 1972, to March 31, 1980.

CONTENTS

Foreword iii
Abstract iv
Alphabetical List of Compounds vi
Figures and Tables viii
Acknowledgement ix

1. Introduction 1
2. Conclusions 3
3. Recommendations. 4
4. Materials and Methods 5
    Selection and Source of Compounds 5
    Adsorbent 5
    Analytical Methods 5
5. Experimental Procedures 7
    Preparation of Carbon Slurry 7
    Preparation of Test Solutions 7
    Validation of Experimental Protocol 8
6. Results and Discussion 11
    Treatment of Isotherm Data 11
    Presentation of Data 12
    Summary of Data .14
7. Isotherms for Individual Compounds 19

References 306
Bibliography 308
Appendices 309
A. Activated Carbon Adsorption Isotherm Protocol 309
B. Published Solubilities of Selected Compounds 315

ALPHABETICAL LIST OF COMPOUNDS

Compound	Page No.
Acenaphthene	20
Acenaphthylene	22
Acetone cyanohydrin	24
Acetophenone	26
2-Acetylaminofluorene	28
Acridine orange	30
Acridine yellow	32
Acrolein	34
Acrylonitrile	36
Adenine	38
Adipic acid	46
Aldrin	42
4-Aminobiphenyl	44
Anethole	46
o-Anisidine	48
Anthracene	50
Benzene	52
Benzidine dihydrochloride	54
Benzoic acid	56
3,4-Benzofluoranthene	58
Benzo(k)fluoranthene	60
Benzo(ghi)perylene	62
Benzo(a)pyrene	64
Benzothiazole	66
alpha-BHC	68
Beta-BHC	70
gamma-BHC (lindane)	72
Bromoform	74
4-Bromophenyl phenyl ether	76
5-Bromouracil	78
Butylamine	80
Butylbenzyl phthalate	82
N-Butyl phthalate	84
Carbon tetrachloride	86
Chlorobenzene	88
Chlordane	90
Chloroethane	92
bis(2-Chloroethoxy)methane	94
bis(2-Chloroethyl)ether	96
2-Chloroethyl vinyl ether	98
Chloroform	100
bis(2-Chloroisopropyl)ether	102
Parachlorometa cresol	104
2-Chloronaphthalene	106
1-Chloro-2-nitrobenzene	108
2-Chlorophenol	110
4-Chlorophenyl phenyl ether	112
5-Chlorouracil	114
Choline chloride	116
Cyclohexanone	118
Cyclohexylamine	120
Cytosine	122
DDE	124
DDT	126
Dibenzo(a,h)anthracene	128
Dibromochloromethane	130
1,2-Dibromo-3-chloropropane	132
1,2-Dichlorobenzene	134
1,3-Dichlorobenzene	136
1,4-Dichlorobenzene	138
3,3-Dichlorobenzidine	140
Dichlorobromomethane	142
1,1-Dichloroethane	144
1,2-Dichloroethane	146
1,2-trans-Dichloroethene	148
1,1-Dichloroethylene	150
2,4-Dichlorophenol	152
1,2-Dichloropropane	154
1,2-Dichloropropene	156
Dieldrin	158

ALPHABETICAL LIST OF COMPOUNDS (continued)

Compound	Page No.
Diethylene glycol	160
Diethyl phthalate	162
4-Dimethylaminoazobenzene	164
N-Dimethylnitrosamine	166
2,4-Dimethylphenol	168
Dimethyl phenyl carbinol	170
Dimethyl phthalate	172
4,6-Dinitro-o-cresol	174
2,4-Dinitrophenol	176
2,4-Dinitrotoluene	178
2,6-Dinitrotoluene	180
Diphenylamine	182
1,1-Diphenylhydrazine	184
1,2-Diphenylhydrazine	186
alpha-Endosulfan	188
beta-Endosulfan	190
Endosulfan sulfate	192
Endrin	194
Ethanol	196
Ethylbenzene	198
Ethylenediamine	200
Ethylenediamine tetraacetic acid	202
bis(2-Ethylhexyl)phthalate	204
Fluoranthene	206
Fluorene	208
5-Fluorouracil	210
Guanine	212
Heptachlor	214
Heptachlor epoxide	216
Hexachlorobenzene	218
Hexachlorobutadiene	220
Hexachlorocyclopentadiene	222
Hexachloroethane	224
Hexamethylenediamine	226
Hydroquinone	228
Isophorone	230
Methylene chloride	232
4,4'-Methylene-bis-(2-chloroaniline)	234
Morpholine	236
Naphthalene	238
alpha-Naphthol	240
beta-Naphthol	242
alpha-Naphthylamine	244
beta-Naphthylamine	246
p-Nitroaniline	248
Nitrobenzene	250
4-Nitrobiphenyl	252
2-Nitrophenol	254
4-Nitrophenol	256
N-Nitrosodiphenylamine	258
N-Nitrosodi-n-propylamine	260
p-Nonylphenol	262
PCB-1221	264
PCB-1232	266
Pentachlorophenol	268
Phenanthrene	270
Phenol	272
Phenylmercuric acetate	274
Styrene	276
1,1,2,2-Tetrachloroethane	278
Tetrachloroethene	280
1,2,3,4-Tetrahydronaphthalene	282
Thymine	284
Toluene	286
1,2,4-Trichlorobenzene	288
1,1,1-Trichloroethane	290
1,1,2-Trichloroethane	292
Trichloroethene	294
Trichlorofluoromethane	296
2,4,6-Trichlorophenol	298
Triethanolamine	300
Uracil	302
p-Xylene	304

FIGURES AND TABLES

Figure Page

1 Percent of equilibrium capacity attained as a function of time 10

Table

1 Effect of Ethanol on Adsorption Capacity of 2-Chlorophenol . 8

2 Reproducibility of Experimental Protocol 9

3 Summary of Carbon Adsorption Capacities 15

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the laboratory and editorial assistance of Michael Jelus. Others who assisted in the laboratory phase include Richard J. Middendorf, Mary Anne Leugers, Richard A. Fiutem, Elmer D. Lipp, and Amy Knipschild.

Carcinogenic compounds specified in the text were investigated by Illinois Institute of Technology Research Institute under Contract No. CI-68-03-2559 and 68-03-2834. Edward G. Fochtman served as Principal Investigator for both contracts.

SECTION 1

INTRODUCTION

A vast number of synthetic organic chemicals are being produced by industry, some of which are introduced into the environment. A measure of the immensity of the problem can be obtained from the American Chemical Society's Chemical Abstract Service whose registry of chemicals lists 4,039,907 distinct entities as of November, 1977. New compounds are being added to the registry at an average rate of about 6,000 per week (1). Of these, Chemical Abstract Service lists some 33,000 chemicals that are thought to be in common use, excluding pesticides, pharmaceuticals, and food additives. Thus, a large number of synthetic organic chemicals are being introduced into the environment. By 1976 some 1,260 organic chemicals were reported found or suspected in fresh water (2) and the list is expanding rapidly as analytical techniques are refined and surveys are conducted on streams, industrial, and municipal wastewaters and potable waters.

The presence of synthetic organic compounds in the environment can have severe adverse effects. These effects include toxicity, carcinogenicity, mutagenicity, or teratogenicity in man and animals, toxicity to aquatic life, and degradation of the quality of water for human consumption. Hence, there is a need to develop control technology capable of removing hazardous organics from water to prevent further dispersion into the environment. Adsorption on powdered or granular activated carbon is being increasingly considered as a method for removal of organic compounds.

While studies on the adsorption of specific organic compounds on activated carbon are extremely limited when the vast number of chemical entities are considered, a substantial number of investigations have been reported. A summary of some of the literature is described below. Linner and Gortner (3) studied a series of 31 organic acids. More recent studies have investigated the adsorption of organic compounds of environmental concern. Morris and Weber (4,5) reported data on the adsorption of phenol, sodium salts of sulfonated organics and pesticides. Adsorption of aromatic acids has been reported by Ward and Getzen (6). Carbon loading values of 300 mg/g of carbon at a residual concentration of 1 mg/l have been reported for the herbicide 2,4-dichlorophenoxyacetic acid (7). Dedrick and Beckman (8) found approximately 20% less adsorption capacity for the same compound. Weber and Gould (9) and DiGiano and Weber (10) investigated the adsorption of organic pesticides including related phenols. Freundlich parameters have been reported for the carbamate insecticides Sevin (1-naphthyl-N- methylcarbamate) and Baygon (2-isopropoxy-N-methylcarbamate) (11). Bernardin and Froelich (12) measured the adsorption of aldrin, dieldrin, endrin, DDT, DDD, DDE, Toxaphene and PCB on activated carbon and were able to achieve residuals of less than

1 ug/1 for each compound in the treated water. Lawrence and Tosine (13) studied the adsorption of polychlorinated biphenyls from aqueous solution and sewage. The effect of molecular structure on the adsorption of substituted benzene compounds was determined by Al-Bahrani and Martin (14). Argaman (15) compared the adsorption of dichloroethane on three different activated carbons. Singer and Yen (16) studied the adsorption of phenol, methylphenol, ethylphenol, dimethylphenol and isopropylphenol on a petroleum-base carbon. Murin and Snoeyink (17) studied the adsorption of 2,4-dichlorophenol and 2,4,6-trichlorophenol at different pH values and determined the effect of humic substances on the adsorption capacity. Removal of methoxychlor from potable water was investigated by Steiner and Singley (18). Adsorption of benzene, toluene, o-xylene and ethylbenzene was investigated by El-Dib and Badawy (19). Peel and Benedek (20) emphasized the kinetic factors in a study on the adsorption of phenol and o-chlorophenol. Fochtman and Dobbs (21) measured the adsorption isotherms for naphthalene, 1,1'--diphenylhydrazine, beta-naphthylamine, 4,4'- methylene bis(2-chloroaniline), benzidine, dimethylnitrosamine, and 3,3'- dichlorobenzidine and described general procedures for handling chemical carcinogens in the research laboratory.

Although the literature contains data on adsorption of specific compounds, the experimental techniques and methods of reporting the data are so varied, that it is difficult to compare adsorbability among compounds. As a result, a major objective of the present study was to standardize the experimental procedure as well as the method of reporting results. Under these conditions, information on adsorption can be compared on a common basis. A second objective was to provide carbon adsorption data for selected compounds of environmental concern. The approach chosen to describe adsorption was batch equilibrium carbon adsorption isotherms with the results plotted according to the Freundlich adsorption equation.

SECTION 2

CONCLUSIONS

The results of experimental studies on the adsorption of priority pollutants and other hazardous organic compounds have shown that activated carbon treatment can effectively remove many of these substances from aqueous solution. Pesticides, polynuclear aromatic hydrocarbons, phthalates, phenolics, and substituted benzenes are readily adsorbed by activated carbon. Certain low molecular weight compounds with high polarity are not amenable to activated carbon treatment. Compounds in this category include low molecular weight amines, nitrosamines, glycols, and certain ethers.

The experimental protocol developed for the isotherm testing provides a simple reproducible procedure for estimating the capacity of activated carbon for adsorption of specific compounds from aqueous solution. The data summary containing the Freundlich parameters and the calculated carbon requirements for granular and powdered carbon treatment simplifies the evaluation of treatability by carbon adsorption.

SECTION 3

RECOMMENDATIONS

Activated carbon adsorption isotherm testing of specific organic compounds should be continued in order to develop a broader base of information for assessing the potential of the process for control of toxic or hazardous compounds. Studies should be directed toward correlation of laboratory isotherm capacity with column loading in treatment operations. Kinetic factors for both granular and powdered carbon treatment need to be investigated. Correlation of adsorption capacities with fundamental molecular properties should be attempted in order to develop the capability to estimate treatability of compounds for which isotherm data are lacking.

Isotherm data for a variety of different activated carbons should be developed using a standard protocol for selected compounds in order to compare adsorption capacities with carbon properties.

SECTION 4

MATERIALS AND METHODS

SELECTION AND SOURCE OF COMPOUNDS

Compounds selected for the present investigation were taken from the following: (1) U.S. Environmental Protection Agency Effluent Guidelines Division list of priority pollutants, (2) Occupational Safety and Health Administration's list of regulated carcinogens, and (3) a list of special interest compounds chosen by the authors.

The organic compounds were used as received from the suppliers: Aldrich Chemical Company, Eastman Organic Chemicals, Chem Service, Inc., and the U.S. Environmental Protection Agency's Health Effects Research Laboratory. Carcinogenic compounds were obtained from National Cancer Institute's Chemical Repository at IIT Research Institute. In general, the compounds assayed greater than 95% and were used without correction for purity.

ADSORBENT

Filtrasorb 300 granular activated carbon, a product of Calgon Corporation, was used as the adsorbent. The granular carbon was pulverized in a ball mill and then screened for classification. Only that portion which passed a 200 mesh (0.0736 mm) screen but was retained by a 400 mesh (0.0381 mm) screen was used for isotherm tests. The carbon was repeatedly milled and screened so that practically all of the original carbon was retained as a powdered sample. After classification the powdered carbon was oven-dried overnight at 105°C, cooled in a desiccator and stored there until needed for experimental purposes. A slurry of the pulverized and screened carbon was prepared in distilled water at an appropriate concentration and the thoroughly wetted carbon suspension was used in the isotherm tests.

ANALYTICAL METHODS

A variety of analytical procedures were used to analyze samples for initial and residual concentration of test compound.

Chlorinated volatile compounds were analyzed by purge and trap gas chromatography as described by Bellar and Lichtenberg (22). A Tenax GC trap was used in conjunction with a 0.2% Carbowax 1500 on 60/80 mesh Carbopack C column. Samples were analyzed using a Tracor Model 222 Gas Chromatograph equipped with a Tracor 310 Hall Electrolytic Detector.

Aromatic and substituted aromatic compounds were generally determined by U-V spectroscopy. A Beckman Model 25 Spectrophotometer equipped with automatic sampler was used to obtain a scan of each test compound in aqueous solution and for the fixed wavelength quantitative measurements.

Solvent extraction - gas chromatography was used for compounds with limited solubility which were not measurable by U-V spectroscopy or purge and trap gas chromatography. The method involved solvent extraction of the aqueous sample with Freon, methylene chloride, or hexane followed by sodium sulfate drying, concentration of the extract in a Kuderna-Danish apparatus, and gas chromatography as reported by Austern, et al., (23). Extracts were analyzed using a Varian Model 3700 gas chromatograph equipped with flame ionization and electron capture detectors.

Polynuclear aromatic hydrocarbons with limited solubility were analyzed by fluorescence spectroscopy. An American Instrument Company Aminco-Bowman Spectrophotofluorometer Model J48960 equipped with Xenon lamp was used for fluorescence measurements. Excitation and emission wavelengths used for analytical purposes are presented on the appropriate data forms.

Several low molecular weight compounds were analyzed with a Beckman Total Organic Carbon Analyzer Model 915B. Samples were acidified and purged for total organic carbon analysis or injected directly for a total carbon measurement. The latter was the method of choice for volatile organics which could not be purged without significant loss of compound.

A more complete description of recommended test procedures for the analysis of priority pollutants has recently been published by the Environmental Monitoring and Support Laboratory of the U.S. Environmental Protection Agency (24).

SECTION 5

EXPERIMENTAL PROCEDURES

A general description of the carbon adsorption isotherm procedure used in the present study is presented in Appendix A. Slight modifications were required for certain compounds. These will be described at the appropriate place in the text.

PREPARATION OF CARBON SLURRY

All isotherm tests were conducted using a thoroughly wetted carbon slurry. The initial slurry was prepared by weighing 50.00 grams of pulverized and screened carbon and diluting to 1.0 liter with distilled water. Other working standard slurries were prepared by serial dilution of the original stock. Desired carbon doses were achieved by using dispensing pipettes of differing volumes. The initial slurry and all serial dilutions were stored in the dark until needed for isotherm testing.

PREPARATION OF TEST SOLUTIONS

Standard solutions of the compounds were prepared in distilled water or mineralized distilled water by several methods. Aqueous solutions of the volatile compounds were prepared by injecting an ethanolic standard solution into the bottle containing distilled water. The bottle was completely filled and capped to minimize loss of compound.

Polynuclear aromatic hydrocarbon stock standard solutions were prepared by injecting a methylene chloride solution of the compound into distilled water and stirring for one to three days to ensure dissolution. Analysis of the resulting solution for methylene chloride at the end of the mixing period indicated complete loss of the solvent. Dissolution of the polynuclear aromatic hydrocarbons was carried out in the dark to avoid photochemical decomposition. Some of the more insoluble polynuclear aromatic compounds were treated by a modified protocol. Standard solutions were prepared using coated-glass beads as described by May and Wasik (25). Each isotherm point corresponding to a single carbon dose required a separate standard solution often at a different initial concentration. Since the initial concentration varied for the series of carbon doses, a modified data reporting form was developed for these cases.

All pesticides and polychlorinated biphenyls were added to the distilled water as an acetone standard solution. Use of an organic solvent facilitates the dissolution of the organic compound in aqueous solution. Minimum quantities of acetone were used and no effect on the isotherm was expected from the small concentrations of solvent because of the very low adsorbability of acetone and the concurrently high adsorption of the pesticides.

Several compounds were weighed and added directly to the distilled water to prepare aqueous solutions. These were mostly solids which were readily soluble in water. Simple aromatic compounds were added as alcoholic solutions.

VALIDATION OF EXPERIMENTAL PROTOCOL

Several aspects of the general isotherm protocol needed to be evaluated in order to validate the proposed procedures. These included: (1) the effect of ethanol on the measured adsorption capacity of a compound, (2) rate of adsorption of compounds to determine whether or not the proposed two-hour contact time was adequate and, (3) reproducibility of the total procedure.

The maximum concentration of ethanol used in the preparation of the aqueous test solutions was 0.008 % w/w (78.9 mg/l). In most cases ethanol concentrations were 0.002 % w/w (15.6 mg/l) or less. Two tests were performed to determine the effect of added ethanol. In the first test an isotherm was obtained using ethanol in aqueous solution as the test compound. The second test determined the effect of the presence of ethanol on the adsorption capacity of 2-chlorophenol. Results are summarized in Table 1.

TABLE 1. EFFECT OF ETHANOL ON ADSORPTION CAPACITY OF 2-CHLOROPHENOL

Wt.% Ethanol* Added	Adsorption Capacity[(a)] (mg/g)	1/n (slope)
0	61	0.38
0.001	56	0.38
0.010	57	0.39
0.100	58	0.33

*Sp. gr. 0.789

(a) Adsorption capacities are calculated at a residual concentration of 1 mg/l in equilibrium with activated carbon at neutral pH.

The rate of adsorption was investigated using three compounds selected to represent acidic, basic, and neutral compounds with weak, moderate, and strong adsorption capacities. The compounds selected were 2-chlorophenol, diphenylamine and 2-chloronaphthalene. Each compound was tested at a concentration of 2.0 mg/l at one carbon dosage. Carbon dosages were selected to remove most of the compound but still leave sufficient residual concentration for analysis by U-V spectroscopy. The resulting data on the approach to equilibrium are presented in Figure 1.

Reproducibility of the experimental isotherm protocol was determined by repetitive measurement of the adsorption capacity for 2-chlorophenol at neutral pH. The results of seven independent isotherm measurements are given in Table 2.

TABLE 2. REPRODUCIBILITY OF EXPERIMENTAL PROTOCOL

Isotherm No.		Adsorption Capacity*, mg/g
1		62.0
2		63.3
3		52.1
4		52.1
5		53.9
6		56.9
7		60.1
	Average	57.1
	Standard deviation	4.7

---

*Calculated for an equilibrium concentration of 1.0 mg/l of 2-chlorophenol.

Successful demonstration of the basic protocol was followed by an extensive program to obtain isotherms for the compounds selected. Isotherms were obtained on all of the desired compounds, with some exceptions. Those excluded were (a) compounds which were gases at room temperature, (b) substances not readily available or not available at reasonable cost, (c) compounds which exhibited some form of instability in aqueous solution. In cases where a series of similar or related compounds were listed, enough members of that class were included in the isotherm study to provide a basis for estimating the adsorbability of members not actually tested. For example, not all PCBs and polynuclear aromatic compounds were tested. However, those that were measured indicate that all of the class are adsorbable. The results are presented on standardized data forms developed to facilitate comparison of adsorption data.

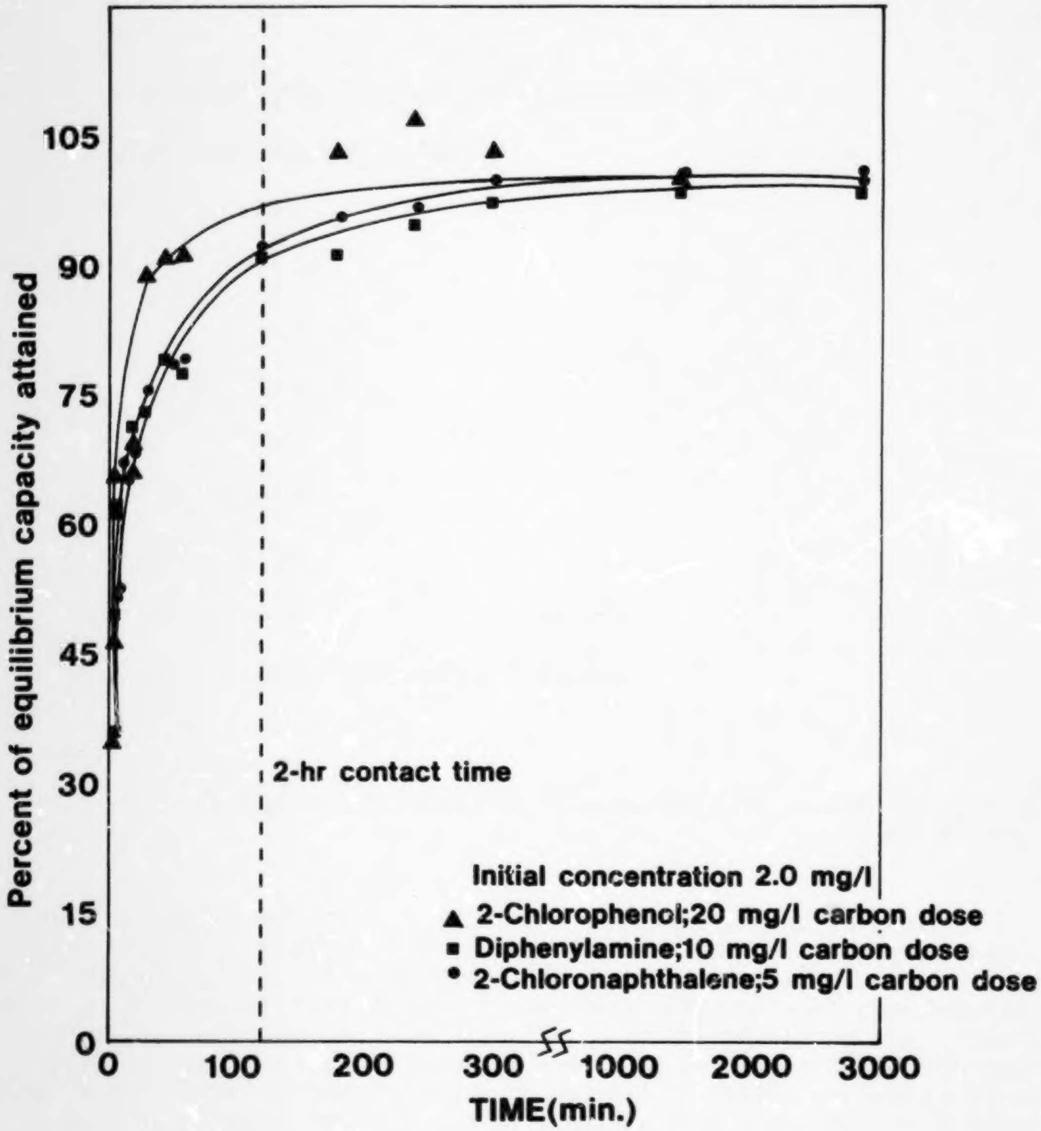


Figure 1. Percent of equilibrium capacity attained as a function of time.

SECTION 6

RESULTS AND DISCUSSION

An attempt to measure an isotherm for ethanol at an initial concentration of 67 mg/l showed less than a 10% reduction in residual concentration for a carbon dose of almost 10 g/l. Therefore, it was concluded that ethanol was not adsorbed and would not compete for adsorption capacity with the test compounds.

Although adsorption from an organic solvent has been reported to be much lower than that obtained from aqueous solution (26) the concentrations of ethanol used in the present study did not alter the adsorption capacity of 2-chlorophenol even when ten times the maximum concentration used in the experimental study was tested as shown in Table 1.

The two-hour contact time specified in the adsorption protocol appears to be adequate for purposes of comparing adsorption characteristics of different compounds. Percent of equilibrium values for the two-hour contact time for 2-chlorophenol, diphenylamine and 2-chloronaphthalene were 92%, 91% and 92%, respectively, as illustrated in Figure 1. In these calculations, equilibrium was considered to be attained after 3,000 minutes, since no further adsorption occurred between 2,000 minutes and 3,000 minutes of contact time. A four-hour contact time would result in slightly greater capacities and may be preferred for some applications. However, other factors, such as purity of the reagents, photochemical effects, variations in different lots of carbon, and method of chemical analysis may all contribute to the measured adsorption capacity in a more significant manner than the additional contact time.

The reproducibility of the total isotherm protocol has been demonstrated to be ± 8.2%. The adsorption capacity for 2-chlorophenol (57.1 ± 4.7 mg/g) at an equilibrium concentration of 1.0 mg/l illustrates the reproducibility that can be expected. Results from another laboratory have been reported on several compounds included in the present study using the protocol presented in Appendix A (27). Results between laboratories were reproducible with deviations less than ± 10%.

TREATMENT OF ISOTHERM DATA

The carbon adsorption data were plotted according to the Freundlich equation. While the equation is empirical it is nonetheless widely used and has been found to describe adequately the adsorption process in dilute solution. The Freundlich equation has the form:

$$X/M = KC_f^{1/n}$$

where:

$X = C_o - C_f$ is the amount of compound adsorbed from a given volume of solution,

M = the weight of activated carbon

C_o = the amount of compound in the untreated solution,

C_f = the amount of compound remaining in the treated water,

K and 1/n are empirical constants characteristic of the compound and carbon used in the test. Graphically, K is the X/M intercept of the isotherm plot at $C_f = 1$ and 1/n is the slope of the line when the equation is plotted on logarithmic paper. The intercept is an indicator of adsorption capacity and the slope of adsorption intensity. The concentration of adsorbate on the adsorbent in equilibrium with a concentration C_f is expressed by X/M. In this study X/M was expressed as mg compound adsorbed per gram of carbon.

Data were fitted to the logarithmic form of the above equation, which has the form:

$$\log X/M = \log K + 1/n \log C_f \qquad (2)$$

PRESENTATION OF DATA

The experimental data for each of the compounds tested are summarized on standardized data forms. Carbon dosages used in the isotherm procedure are shown on the left hand column along with the initial C_o, and residual concentrations after treatment with pulverized activated carbon. Data are expressed in mg/l. These values were then used to calculate the amount of compound removed (C_o-C_f) and the carbon loading, X/M expressed as mg/g. The data were plotted according to equation(2) on logarithmic paper. Linear least squares regression analysis was used to locate the isotherm line. Some of the compounds were tested at differing pH's. When pH affected adsorption, individual lines were drawn to show the effect of pH. If pH had no observable effect on adsorption, all of the data points were plotted and represented by a single line.

On the first page of the data form for each compound, the molecular structure, formula and molecular weight are given. The equation of the regression line was used to calculate the values for the intercept, K, and the slope 1/n. The K value represents the carbon loading, X/M, in mg compound/gram of carbon at an equilibrium concentration of 1.0 mg/l of compound. K values were summarized at this concentration for comparison purposes even though 1.0 mg/l exceeded the solubility of several of the compounds tested. Thus, some K values for the extremely insoluble compounds represent a substantial extrapolation of the data by as much as two or three orders of magnitude. Available information on the solubility of test compounds is presented in Appendix B. Also shown on the data form is the correlation coefficient, r, for the linear regression analysis.

As the Freundlich equation indicates, the loading on the carbon, X/M, is a function of the equilibrium concentration of organic compound after carbon treatment. This effect is shown in the next table on the data sheet. The adsorption capacity in mg/gram for varying equilibrium concentrations of organic compound ranging from 0.001 to 1.0 mg/l, were calculated from the equation of the regression line.

The Freundlich equation can be rearranged to calculate the carbon dose required to reduce any initial concentration of compound to some predetermined residual concentration. If, for the term X, use is made of its equivalent, C_o-C_f, in which C_o equals the initial concentration of organic compound and C_f the residual concentration, the equation can now be written as follows:

$$\frac{C_o-C_f}{M} = KC_f^{1/n} \qquad (3)$$

Equation 3 can be solved directly for the carbon dose required or the equation can be rearranged to the logarithmic form:

$$\log (C_o-C_f)-\log M = \log K + 1/n \log C_f \qquad (4)$$

Equation 3 is linear when M (carbon dose) is plotted against C_o initial concentration on ordinary coordinate paper. These calculations were made for a range of initial and final concentrations. The resulting carbon doses are tabulated in mg/l for neutral pH in the bottom table of the data sheet (solution of equations 3 and 4 gives M = grams/liter if C_o and C_f are in mg/l and K is in mg/g). For compounds which were essentially non-adsorbable, the calculated carbon dosages were considered too high to be practical and are shown in the table as greater than 100,000 mg/l carbon.

The tabulated carbon doses represent removals obtainable in a single-stage contactor. More efficient use of carbon can be realized by multiple stages of contacting. The carbon dose values are, however, useful for comparative purposes and to ascertain whether use of carbon is feasible for removal of a compound.

Data are provided to calculate the carbon dose to reduce any initial concentration of a compound to any desired final concentration. For example, consider the following for benzidine. To calculate the carbon required to reduce a benzidine concentration from 10 mg/l to 0.1 mg/l in neutral solution, equation 4 is used. Values for the constants are taken from the first page of the data sheets for benzidine. Thus,

$$\log (10-0.1)-\log M = \log 220 + 0.37 \log 0.1$$

$$M = 0.100 \text{ g/l or } 100 \text{ mg/l}$$

The tabulated carbon doses are also useful to illustrate the benefit of more than one stage of treatment. Consider again the case of benzidine. To reduce an initial concentration of 10 mg/l to 0.1 mg/l in a single stage requires 100 mg/l of activated carbon. If removal is accomplished in two stages; i.e., 10 mg/l to 1.0 mg/l in the first stage followed by 1.0 mg/l to 0.1 mg/l in a second stage, the carbon dose is 40 mg/l + 9.4 mg/l = 49.4 mg/l of carbon or about one-half the dose required in a single stage process.

The ultimate number of stages in a carbon adsorption system is achieved in column operation. Carbon requirements for column adsorption systems can be estimated from the Freundlich equation. To estimate the granular carbon requirements for column operation obtain the adsorption capacity from the isotherm plot for the concentration of compound to be treated. This capacity designated $(X/M)_{C_0}$ is the ultimate capacity of the carbon for the adsorbate at that concentration (C_0). This capacity represents the ultimate loading for a single component solution that can be attained during granular carbon column treatment, if the column is operated until the adsorbate concentration in the effluent is equal to the influent. Granular carbon requirement (G_C) can be calculated from the following equation:

$$G_C = \frac{C_0}{(X/M)_{C_0}} \qquad (5)$$

If C_0 is in mg/l and X/M is in mg/g carbon requirements will be in g/l. Multiplication by 1,000 gives mg/l and multiplication of that product by 8.337 gives pounds per million gallons to be treated. For example, consider the case of granular carbon treatment of a solution containing 1 mg/l of benzidine (C_0 = 1.0 mg/l; X/M = 220 mg/g). Solution of equation 5 yields:

$$G_C = \frac{1}{220} = 0.0045 \text{ g/l or } 4.5 \text{ mg/l}$$

SUMMARY OF DATA

A summary of the adsorption capacities for all of the compounds tested (at neutral pH) are shown in Table 3. The values are arranged in descending order. The constant, K, expressed as mg compound/gram of carbon, corresponds to the capacity, X/M, when the equilibrium concentration of compound is 1.0 mg/l.

Activated carbon exhibits a broad range of effectiveness in adsorbing organic compounds. Low molecular weight compounds with polar characteristics are not well adsorbed, if at all. Pesticides, polychlorinated biphenyls, polynuclear aromatic hydrocarbons, phthalates, aromatic, and substituted aromatic compounds were strongly adsorbed on activated carbon. Treatability of water and wastewater for removal of organics can be evaluated using the isotherm procedure.

TABLE 3. SUMMARY OF CARBON ADSORPTION CAPACITIES

Compound	Adsorption[a] Capacity, mg/g
bis(2-Ethylhexyl) phthalate	11,300
Butylbenzyl phthalate	1,520
Heptachlor	1,220
Heptachlor epoxide	1,038
Endosulfan sulfate	686
Endrin	666
Fluoranthene	664
Aldrin	651
PCB-1232	630
beta-Endosulfan	615
Dieldrin	606
Hexachlorobenzene	450
Anthracene	376
4-Nitrobiphenyl	370
Fluorene	330
DDT	322
2-Acetylaminofluorene	318
alpha-BHC	303
Anethole*	300
3,3-Dichlorobenzidine	300
2-Chloronaphthalene	280
Phenylmercuric Acetate	270
Hexachlorobutadiene	258
gamma-BHC (lindane)	256
p-Nonylphenol	250
4-Dimethylaminoazobenzene	249
Chlordane	245
PCB-1221	242
DDE	232
Acridine yellow*	230
Benzidine dihydrochloride	220
beta-BHC	220
N-Butylphthalate	220
N-Nitrosodiphenylamine	220
Phenanthrene	215
Dimethylphenylcarbinol*	210
4-Aminobiphenyl	200
beta-Naphthol*	200
alpha-Endosulfan	194
Acenaphthene	190
4,4' Methylene-bis-(2-chloroaniline)	190
Benzo(k)fluoranthene	181
Acridine orange*	180
alpha-Naphthol	180
4,6-Dinitro-o-cresol	169
alpha-Naphthylamine	160
2,4-Dichlorophenol	157
1,2,4-Trichlorobenzene	157
2,4,6-Trichlorophenol	155
beta-Naphthylamine	150
Pentachlorophenol	150
2,4-Dinitrotoluene	146
2,6-Dinitrotoluene	145
4-Bromophenyl phenyl ether	144
p-Nitroaniline*	140
1,1-Diphenylhydrazine	135
Naphthalene	132
1-Chloro-2-nitrobenzene	130
1,2-Dichlorobenzene	129
p-Chlorometacresol	124
1,4-Dichlorobenzene	121
Benzothiazole*	120
Diphenylamine	120
Guanine*	120
Styrene	120
1,3-Dichlorobenzene	118
Acenaphthylene	115
4-Chlorophenyl phenyl ether	111
Diethyl phthalate	110

TABLE 3. SUMMARY OF CARBON ADSORPTION CAPACITIES (cont.)

Compound	Adsorption(a) Capacity, mg/g
2-Nitrophenol	99
Dimethyl phthalate	97
Hexachloroethane	97
Chlorobenzene	91
p-Xylene	85
2,4-Dimethylphenol	78
4-Nitrophenol	76
Acetophenone	74
1,2,3,4-Tetrahydronaphthalene	74
Adenine*	71
Dibenzo(a,h)anthracene	69
Nitrobenzene	68
3,4-Benzofluoranthene	57
1,2-Dibromo-3-chloropropane	53
Ethylbenzene	53
2-Chlorophenol	51
Tetrachloroethene	51
o-Anisidine*	50
5 Bromouracil	44
Benzo(a)pyrene	34
2,4-Dinitrophenol	33
Isophorone	32
Trichloroethene	28
Thymine*	27
Toluene	26
5-Chlorouracil*	25
N-Nitrosodi-n-propylamine	24
bis(2-Chloroisopropyl) ether	24
Phenol	21
Bromoform	20
Carbon tetrachloride	11
bis(2-Chloroethoxy) methane	11
Uracil*	11
Benzo(ghi)perylene	11
1,1,2,2-Tetrachloroethane	11
1,2-Dichloropropene	8.2
Dichlorobromomethane	7.9
Cyclohexanone*	6.2
1,2-Dichloropropane	5.9
1,1,2-Trichloroethane	5.8
Trichlorofluoromethane	5.6
5-Fluorouracil*	5.5
1,1-Dichloroethylene	4.9
Dibromochloromethane	4.8
2-Chloroethyl vinyl ether	3.9
1,2-Dichloroethane	3.6
1,2-trans-Dichloroethene	3.1
Chloroform	2.6
1,1,1-Trichloroethane	2.5
1,1-Dichloroethane	1.8
Acrylonitrile	1.4
Methylene chloride	1.3
Acrolein	1.2
Cytosine*	1.1
Benzene	1.0
Ethylenediaminetetraacetic acid	0.86
Benzoic acid	0.76
Chloroethane	0.59
N-Dimethylnitrosamine	6.8×10^{-5}

TABLE 3. SUMMARY OF CARBON ADSORPTION CAPACITIES (cont.)

NOT ADSORBED

- Acetone cyanohydrin
- Adipic acid
- Butylamine
- Choline chloride
- Cyclohexylamine
- Diethylene glycol
- Ethanol
- Hexamethylenediamine
- Hydroquinone
- Morpholine
- Triethanolamine

*Compounds prepared in "mineralized" distilled water containing the following composition:

Ion	Conc., mg/l	Ion	Conc., mg/l
Na^+	92	$PO_4^{\equiv}$	10
K^+	12.6	$SO_4^{=}$	100
Ca^{++}	100	Cl^-	177
Mg^{++}	25.3	Alkalinity	200

(a) Adsorption capacities are calculated for an equilibrium concentration of 1.0 mg/l at neutral pH.

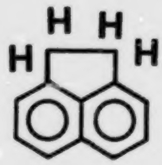
SECTION 7

ISOTHERMS FOR INDIVIDUAL COMPOUNDS

Preceding page blank

COMPOUND: Acenaphthene

STRUCTURE:



FORMULA: $C_{12}H_{10}$ **MOL. WT.** 154.21

FREUNDLICH PARAMETERS	pH		
	5.3		
K	190		
1/n	0.36		
Corr. Coef. r	0.82		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	190		
0.1	84		
0.01	37.0		
0.001	16		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	10	30	60
0.1		2.4	6.1
0.01			0.6

GRANULAR CARBON COLUMN

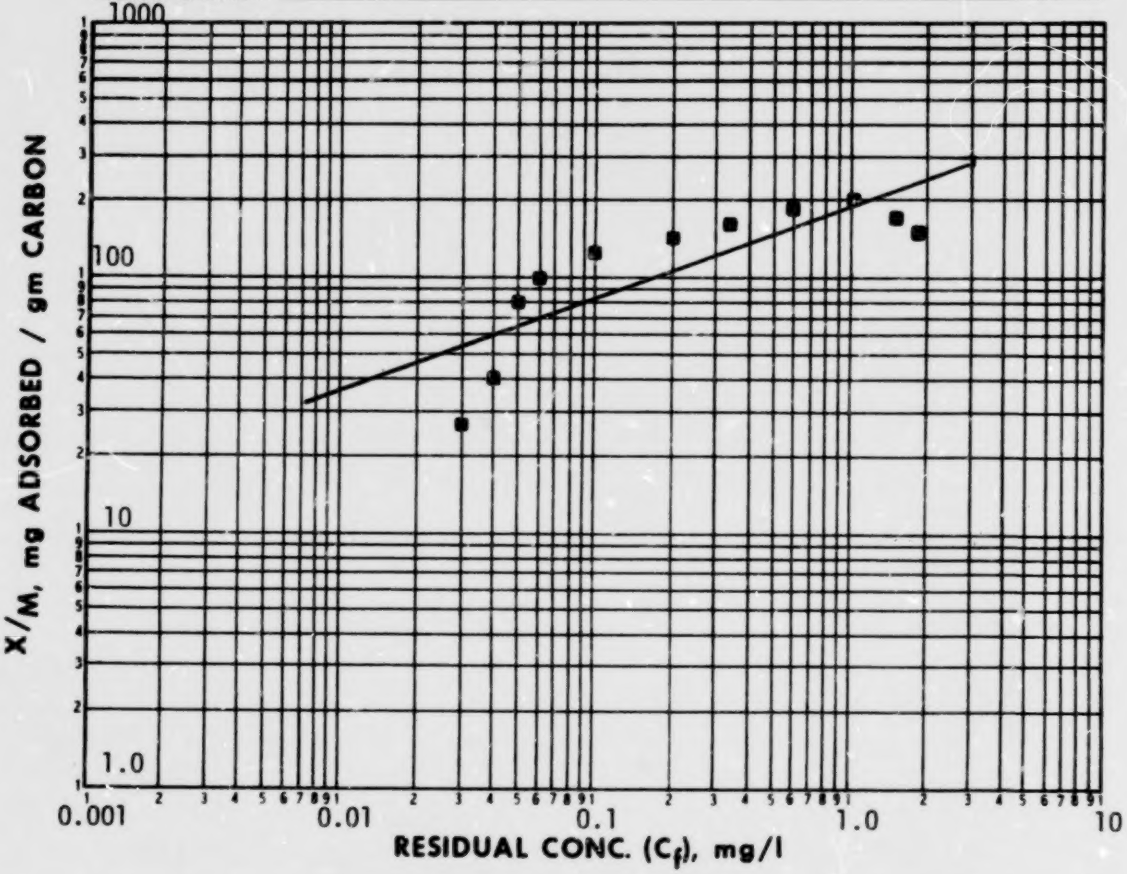
C_o, mg/l	
1.0	5.2
0.1	1.2
0.01	0.3

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 226 nm.

REMARKS:

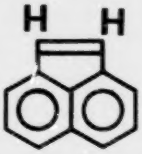
COMPOUND: Acenaphthene



	● pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	**C$_f$**	**C$_o$–C$_f$=X**	**X/M**	**C$_f$**	**C$_o$-C$_f$=X**	**X/M**	**C$_f$**	**C$_o$-C$_f$=X**	**X/M**
0	2.04								
1.0	1.88	0.16	160						
2.5	1.60	0.44	176						
5.0	1.04	1.00	200						
7.5	0.60	1.44	192						
10	0.33	1.71	171						
12.5	0.20	1.84	147						
15	0.10	1.94	129						
20	0.06	1.98	99						
25	0.05	1.99	80						
50	0.04	2.00	40						
75	0.03	2.01	27						

COMPOUND: Acenaphthylene

STRUCTURE:



FORMULA: $C_{12}H_8$ **MOL. WT.** 152.21

FREUNDLICH PARAMETERS	pH		
	5.3		
K	115		
1/n	0.37		
Corr. Coef. r	0.90		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	115		
0.1	49		
0.01	21		
0.001	9.0		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	18	47	110
0.1		4.3	11
0.01			1.0

GRANULAR CARBON COLUMN

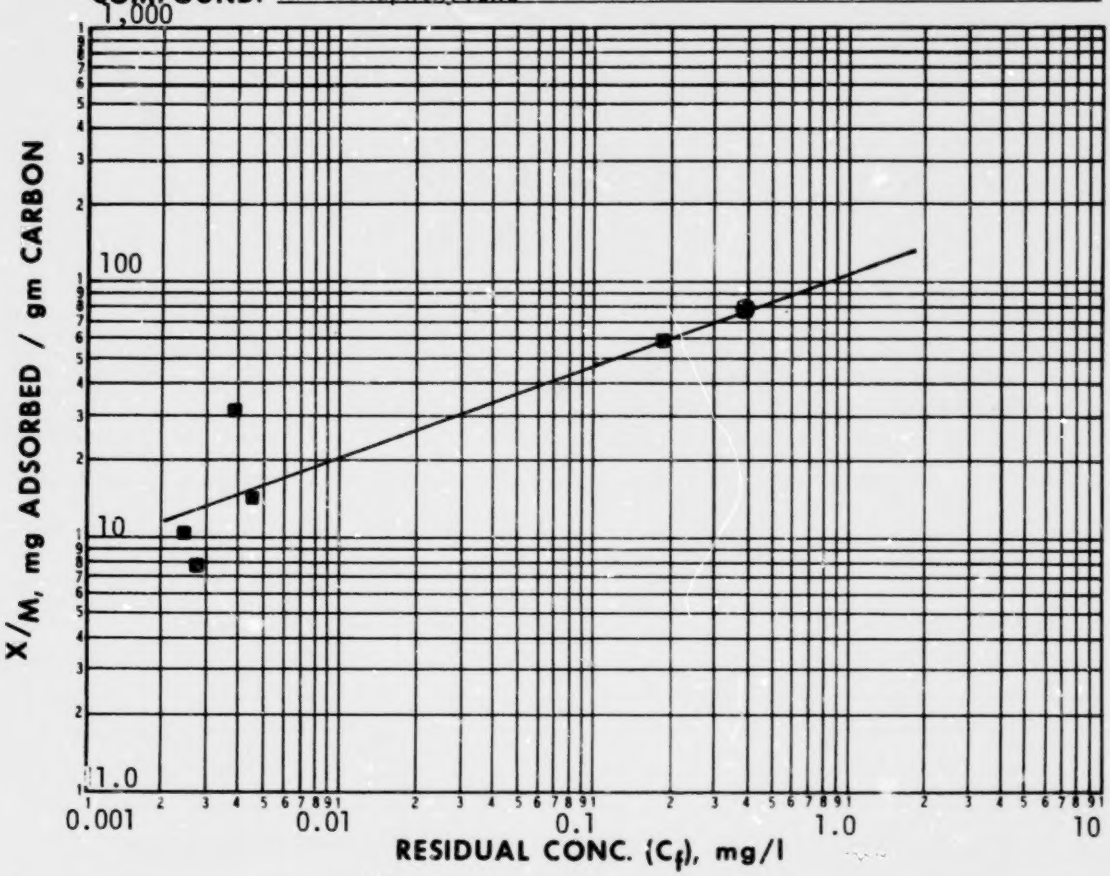
C_o, mg/l	
1.0	8.7
0.1	2.0
0.01	0.5

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent Extraction - G.C.

REMARKS:

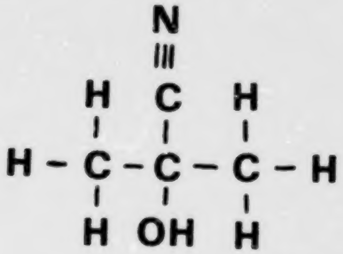
COMPOUND: Acenaphthylene



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	0.790								
5	0.392	0.398	79.6						
10	0.191	0.599	59.9						
25	0.0039	0.786	31.4						
50	0.0045	0.786	15.7						
75	0.0025	0.788	10.5						
100	0.0028	0.787	7.87						

COMPOUND: Acetone cyanohydrin

STRUCTURE:



FORMULA: C_4H_7NO **MOL. WT.** 85.11

FREUNDLICH PARAMETERS	pH		
K			
1/n			
Corr. Coef. r			
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_0, mg/l			

GRANULAR CARBON COLUMN

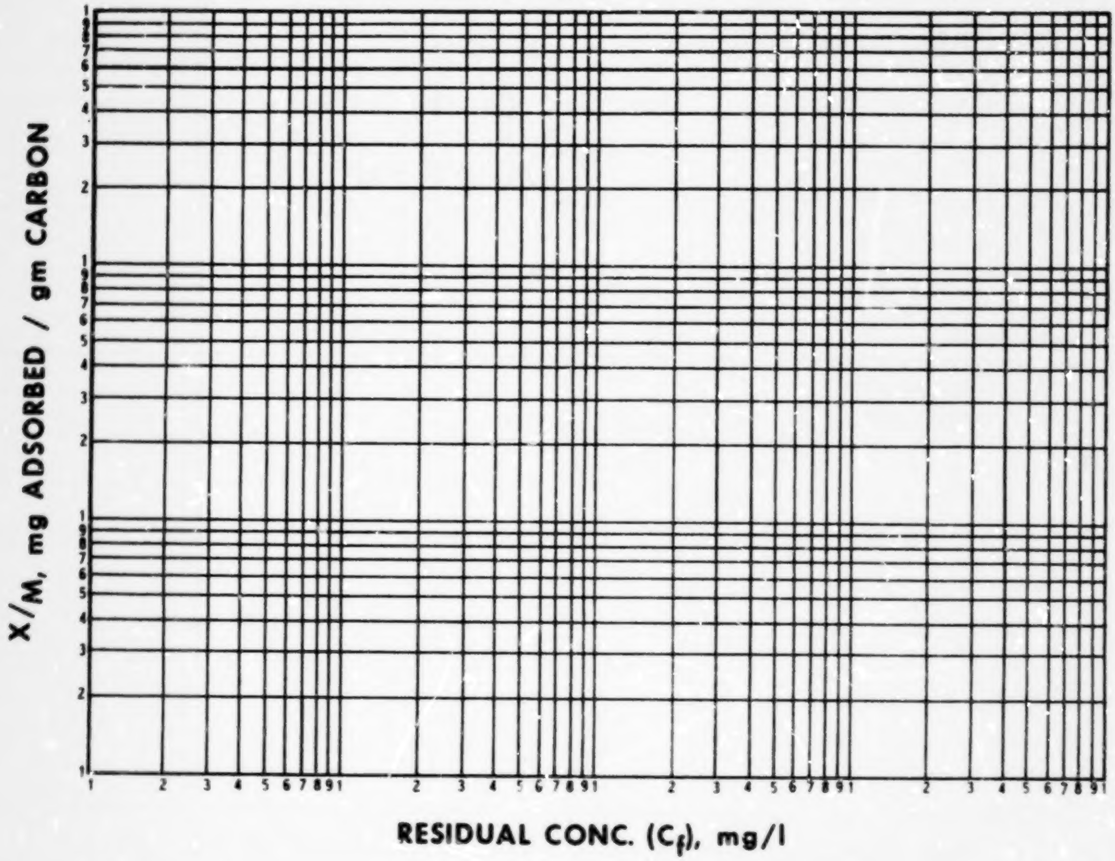
C_0, mg/l	

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Total Organic Carbon

REMARKS: Not adsorbed

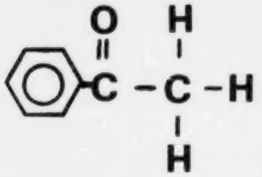
COMPOUND: Acetone cyanohydrin



	pH= 3.01			**pH=** 7.03			**pH=** 8.97		
CARBON DOSE mg/l	**C_f**	**$C_o-C_f=X$**	**X/M**	**C_f**	**$C_o-C_f=X$**	**X/M**	**C_f**	**$C_o-C_f=X$**	**X/M**
0	11.4			10.2			11.8		
5	11.0			9.4			10.2		
10	17.2			9.2			10.0		
25	13.4			10.2			8.6		
50	16.2			14.4			9.0		
100	20.5			12.6			8.6		
150	13.0			9.8			8.8		
200	10.6			9.0			9.4		

COMPOUND: Acetophenone

STRUCTURE:



FORMULA: C_8H_8O **MOL. WT.** 120.14

FREUNDLICH PARAMETERS	pH		
	All data pooled		
K	74		
1/n	0.44		
Corr. Coef. r	0.97		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	200		
1.0	74		
0.1	27		
0.01	9.8		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	34	100	230
0.1		9.2	28
0.01			2.5

GRANULAR CARBON COLUMN

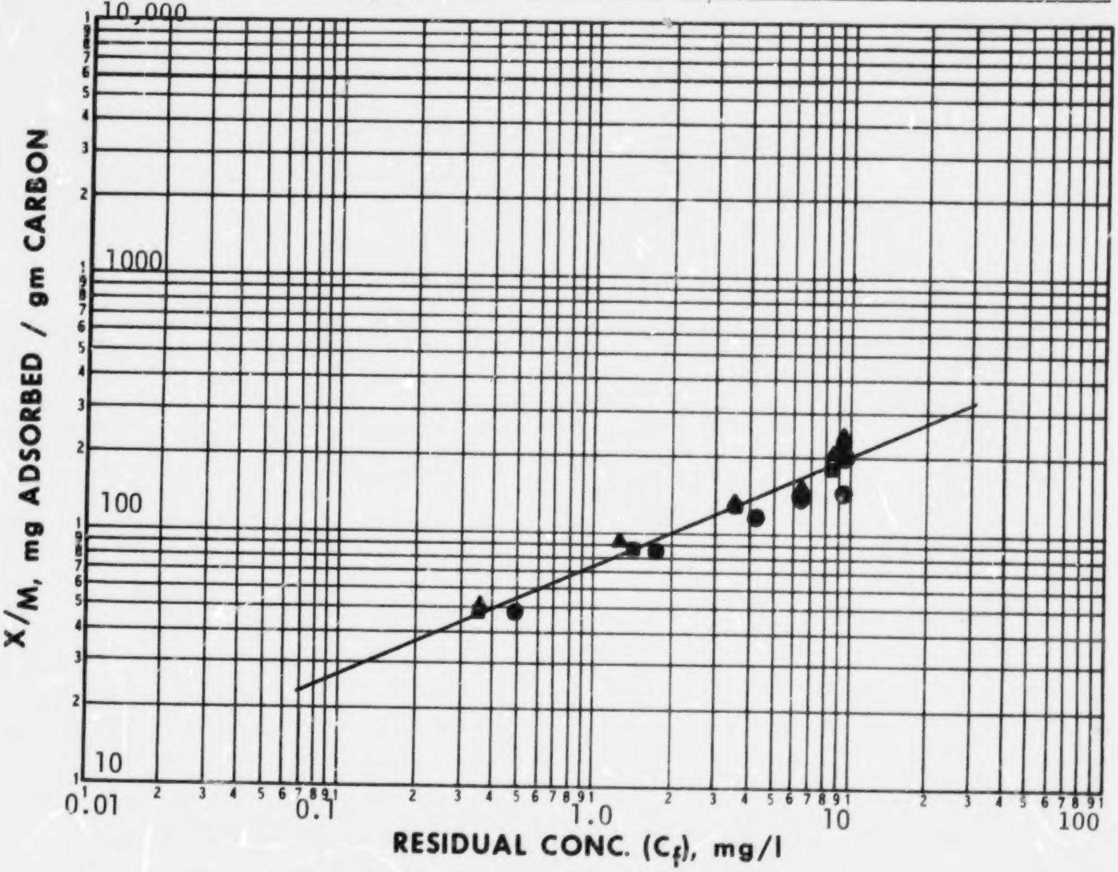
C_o, mg/l	
1.0	14
0.1	3.7
0.01	1.0

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 244 nm

REMARKS:

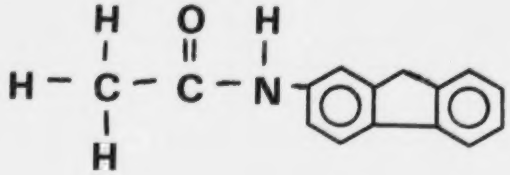
COMPOUND: Acetophenone



	● pH= 3.0			■ pH=7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	10.30			10.20			10.50		
2.5	9.80	0.50	200						
5	9.50	0.80	160	9.10	1.10	220	9.25	1.25	250
10				8.35	1.85	185	8.45	2.05	205
25	6.58	3.72	149	6.33	3.87	154	6.30	4.20	168
50	4.15	6.15	123	3.65	6.55	131	3.48	7.02	140
100	1.82	8.48	85	1.52	8.68	87	1.30	9.20	92
200	0.50	9.80	49	0.36	9.84	49	0.36	10.14	51

COMPOUND: 2-Acetylaminofluorene

STRUCTURE:



FORMULA: $C_{15}H_{13}NO$ **MOL. WT.** 222.28

FREUNDLICH PARAMETERS	pH		
	7.1		
K	318		
1/n	0.12		
Corr. Coef. r	0.94		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	318		
0.1	240		
0.01	180		
0.001	140		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	3.7	5.4	7.2
0.1		0.5	0.7
0.01			0.06

GRANULAR CARBON COLUMN

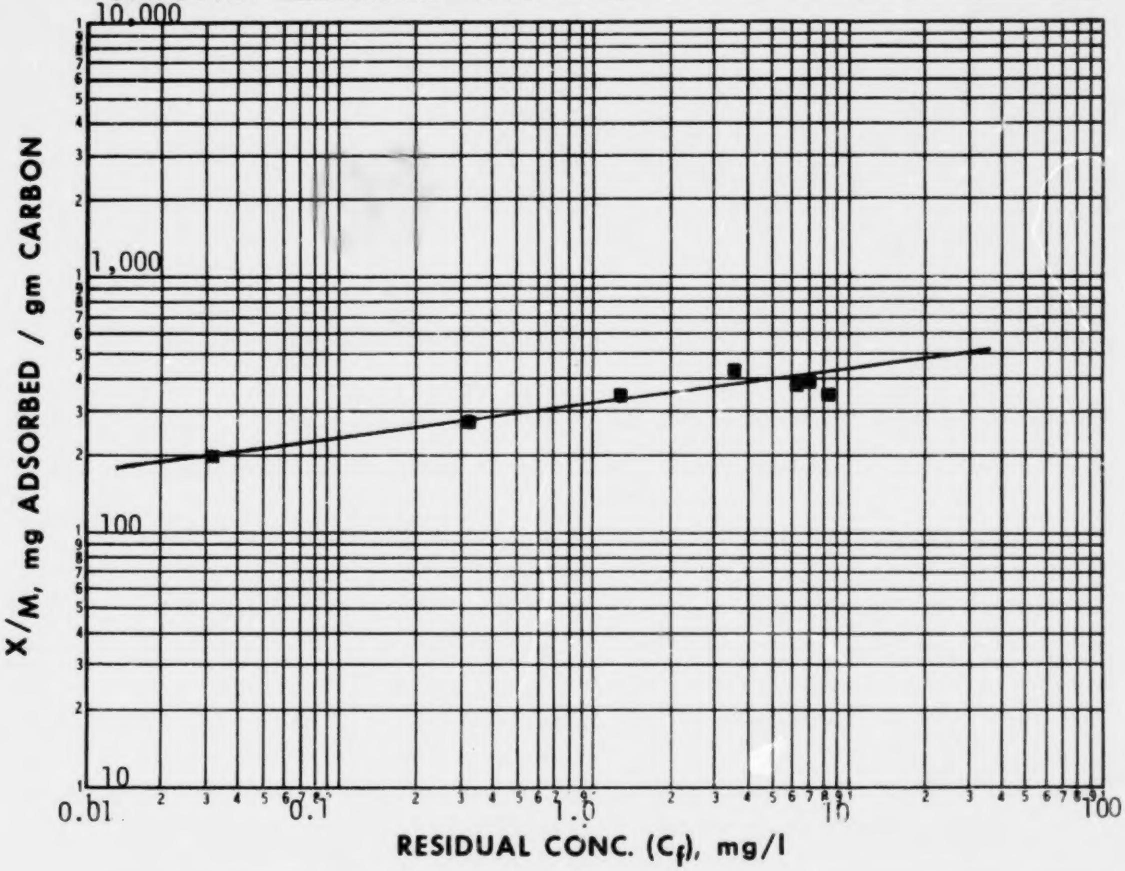
C_o, mg/l	
1.0	3.1
0.1	0.42
0.01	0.06

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 270 nm

REMARKS: OSHA regulated carcinogen

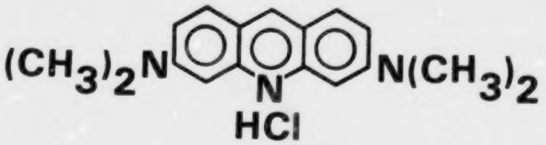
COMPOUND: 2-Acetylaminofluorene



	■ pH= 7.1			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	10.02								
5	8.20	1.82	364						
7.5	7.05	2.97	396						
10	6.20	3.82	382						
15	3.55	6.47	431						
25	1.28	8.74	350						
35	0.32	9.70	277						
50	0.032	9.99	200						

COMPOUND: Acridine orange

STRUCTURE:



FORMULA: $C_{17}H_{19}N_3.HCl$ **MOL. WT.** 301.82

FREUNDLICH PARAMETERS	pH		
	pH 3 and 7 pooled	9.0	
K	180	210	
1/n	0.29	0.38	
Corr. Coef. r	0.97	0.99	
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	350	500	
1.0	180	210	
0.1	91	88	
0.01	46	37	

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	9.9	21	42
0.1		1.9	4.2
0.01			0.38

GRANULAR CARBON COLUMN

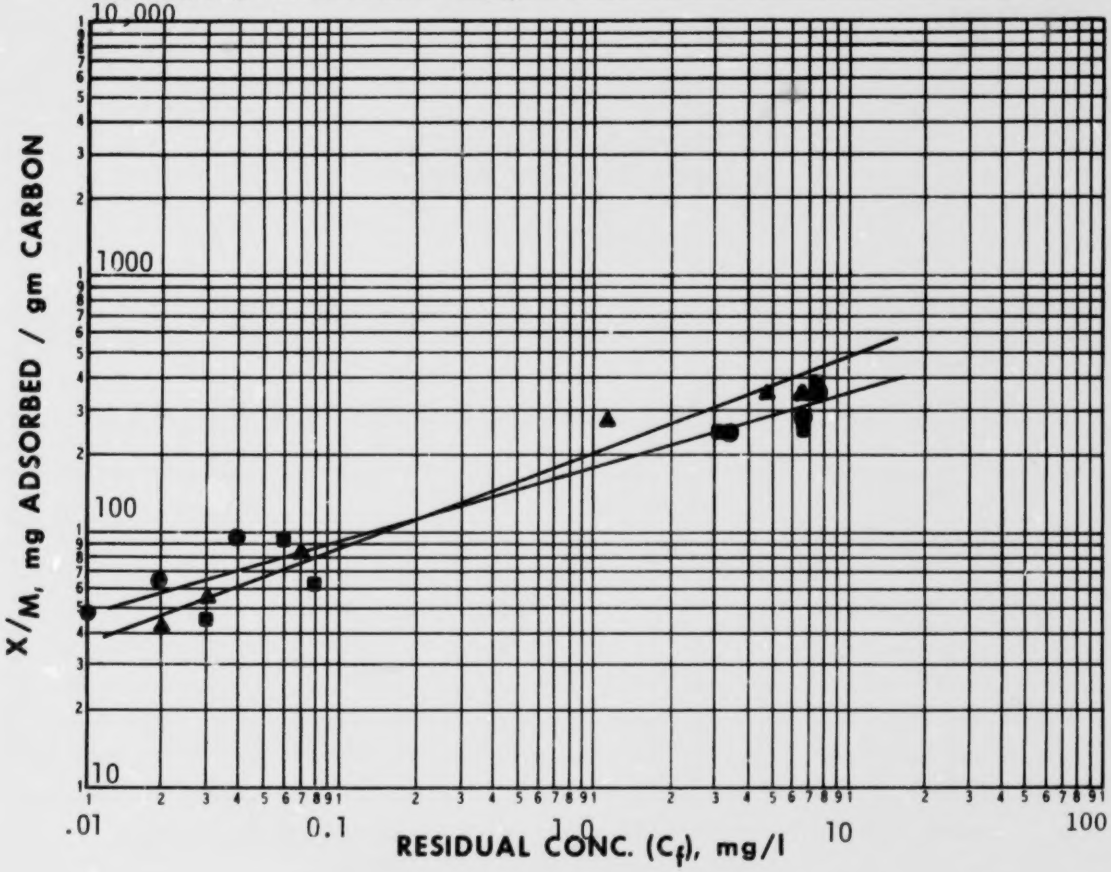
C_o, mg/l	
1.0	5.6
0.1	1.1
0.01	0.2

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Visible Spectroscopy 492 nm

REMARKS:

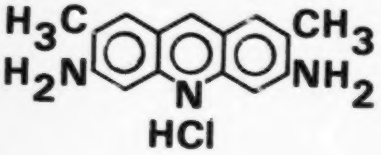
COMPOUND: Acridine orange



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	9.59			9.29			8.36		
5	7.78	1.81	362	7.35	1.94	388	6.56	1.80	360
10	6.71	2.88	288	6.74	2.55	255	4.74	3.62	362
25	3.38	6.21	248	3.14	6.15	246	1.22	7.14	286
100	0.04	9.55	96	0.06	9.23	92	0.07	8.29	83
150	0.02	9.57	64	0.08	9.21	61	0.03	8.33	56
200	0.01	9.58	48	0.03	9.26	46	0.02	8.34	42

COMPOUND: Acridine yellow

STRUCTURE:



FORMULA: $C_{15}H_{15}N_3 \cdot HCl$ **MOL. WT.** 273.77

FREUNDLICH PARAMETERS	pH		
	3.0	ph 7 and 9 pooled	
K	210	230	
1/n	0.14	0.12	
Corr. Coef. r	0.72	0.88	
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	290	300	
1.0	210	230	
0.1	150	180	
0.01	110	135	

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	5.1	7.4	9.9
0.1		0.67	0.98
0.01			0.09

GRANULAR CARBON COLUMN

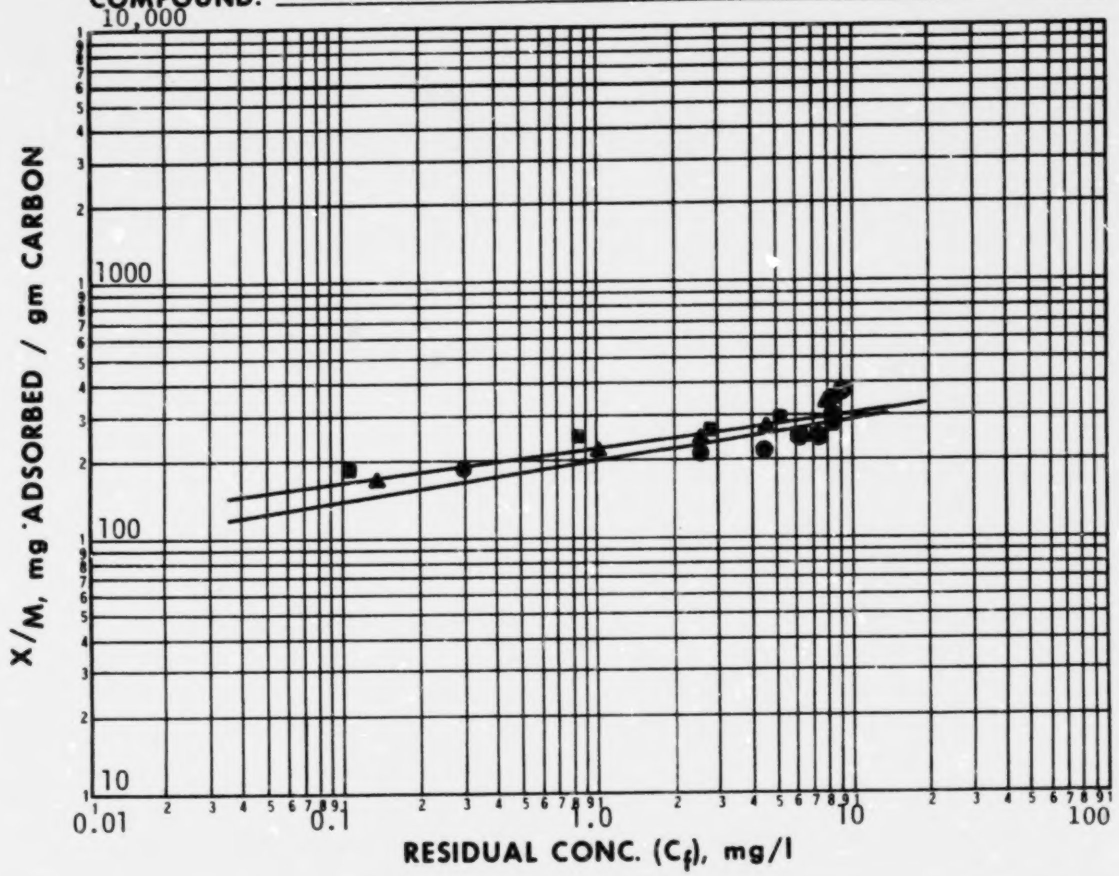
C_o, mg/l	
1.0	4.3
0.1	0.6
0.01	0.1

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 264 nm

REMARKS:

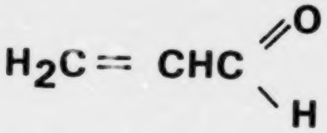
COMPOUND: Acridine yellow



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	10.01			9.54			8.82		
2.5	9.06	0.95	380	8.67	0.87	348	7.97	0.85	340
5	8.51	1.50	300	8.17	1.37	274			
10	7.49	2.52	252	7.08	2.46	246	6.25	2.57	257
15	6.16	3.85	257	5.05	4.48	299	4.61	4.21	281
25	4.55	5.46	218	2.84	6.70	268	2.60	6.22	249
35	2.72	7.29	208	0.83	8.71	248	1.01	7.81	223
50	0.30	9.71	194	0.11	9.43	188	0.14	8.68	173

COMPOUND: Acrolein

STRUCTURE:



FORMULA: C_3H_4O **MOL. WT.** 56.06

FREUNDLICH PARAMETERS	pH		
	5.2		
K	1.2		
1/n	0.65		
Corr. Coef. r	0.98		
INITIAL CONC. mg/l	**ADSORPTION CAPACITY, mg/gm**		
10	5.2		
1.0	1.2		
0.1	0.26		
0.01	0.06		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON
C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	3,500	17,000	76,800
0.1		1,500	7,600
0.01			690

GRANULAR CARBON COLUMN

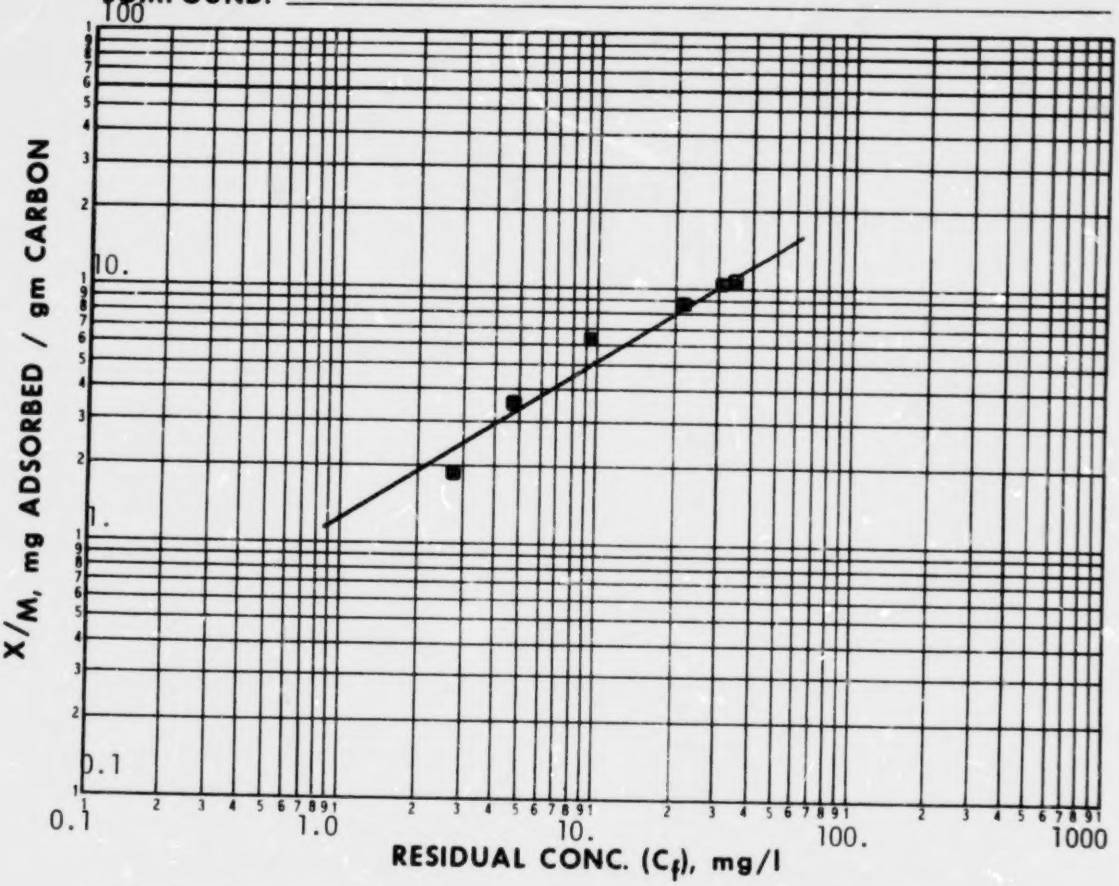
C_o, mg/l	
1.0	860
0.1	380
0.01	170

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Total Carbon

REMARKS:

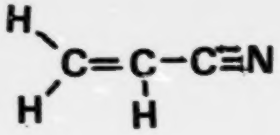
COMPOUND: Acrolein



	■ pH= 5.2			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	40.33								
500	34.98	5.35	10.70						
1,000	30.30	10.03	10.03						
2,000	22.41	17.92	8.96						
5,000	9.58	30.75	6.15						
10,000	4.77	35.56	3.56						
20,000	2.76	37.57	1.88						

COMPOUND: Acrylonitrile

STRUCTURE:



FORMULA: C_3H_3N **MOL. WT.** 53.06

FREUNDLICH PARAMETERS	pH		
	5.8		
K	1.4		
1/n	0.51		
Corr. Coef. r	0.99		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1	1.4		
0.1	0.42		
0.01	0.13		
0.001	0.04		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	2,200	7,700	25,000
0.1		700	2,500
0.01			230

GRANULAR CARBON COLUMN

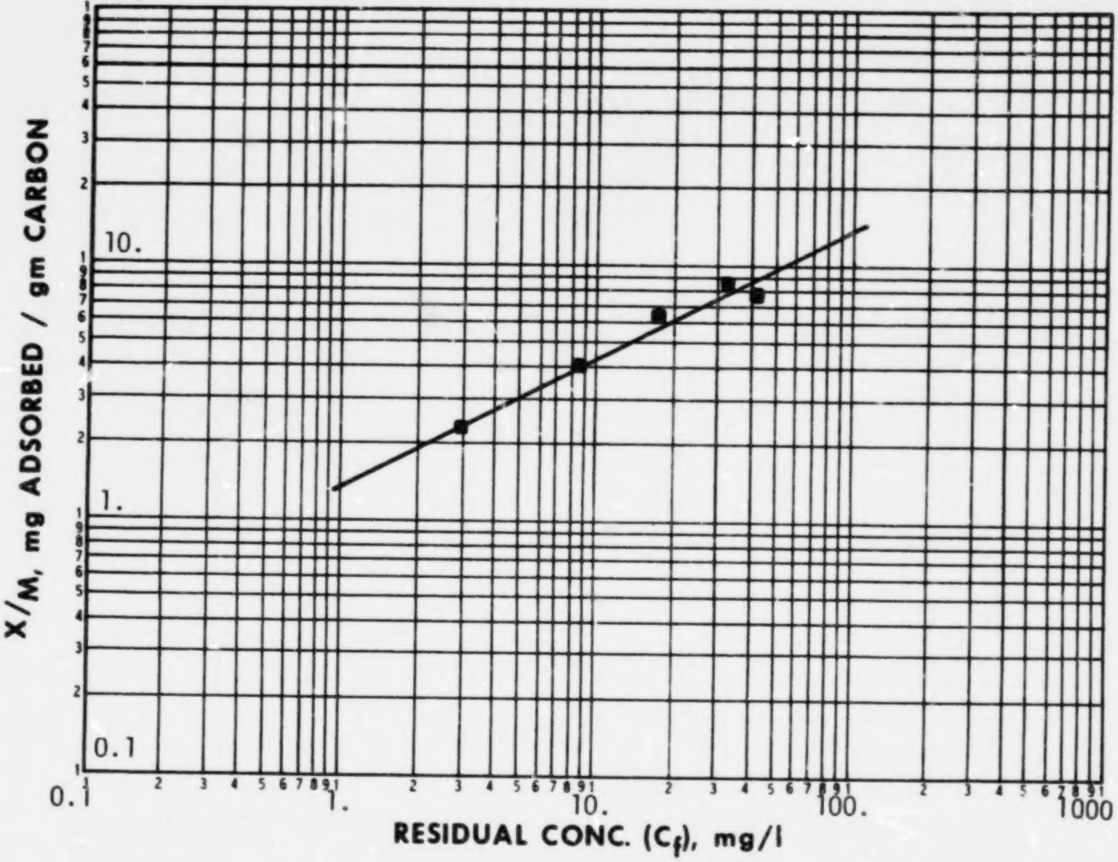
C_o, mg/l	
1.0	710
0.1	240
0.01	80

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Total Carbon

REMARKS:

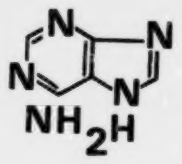
COMPOUND: Acrylonitrile



	● pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	48.70								
1,000	40.85	7.85	7.85						
2,000	31.77	16.93	8.47						
5,000	17.86	30.84	6.17						
10,000	8.68	40.02	4.00						
20,000	2.98	45.72	2.29						

COMPOUND: Adenine

STRUCTURE:



FORMULA: $C_5H_5N_5$ **MOL. WT.** 135.13

FREUNDLICH PARAMETERS	pH		
	3.0	pH 7 and 9 pooled	
K	38	71	
1/n	0.38	0.38	
Corr. Coef. r	0.97	0.96	
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	91	170	
1.0	38	71	
0.1	16	30	
0.01	6.5	12	

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	30	80	190
0.1		7.3	19
0.01			1.7

GRANULAR CARBON COLUMN

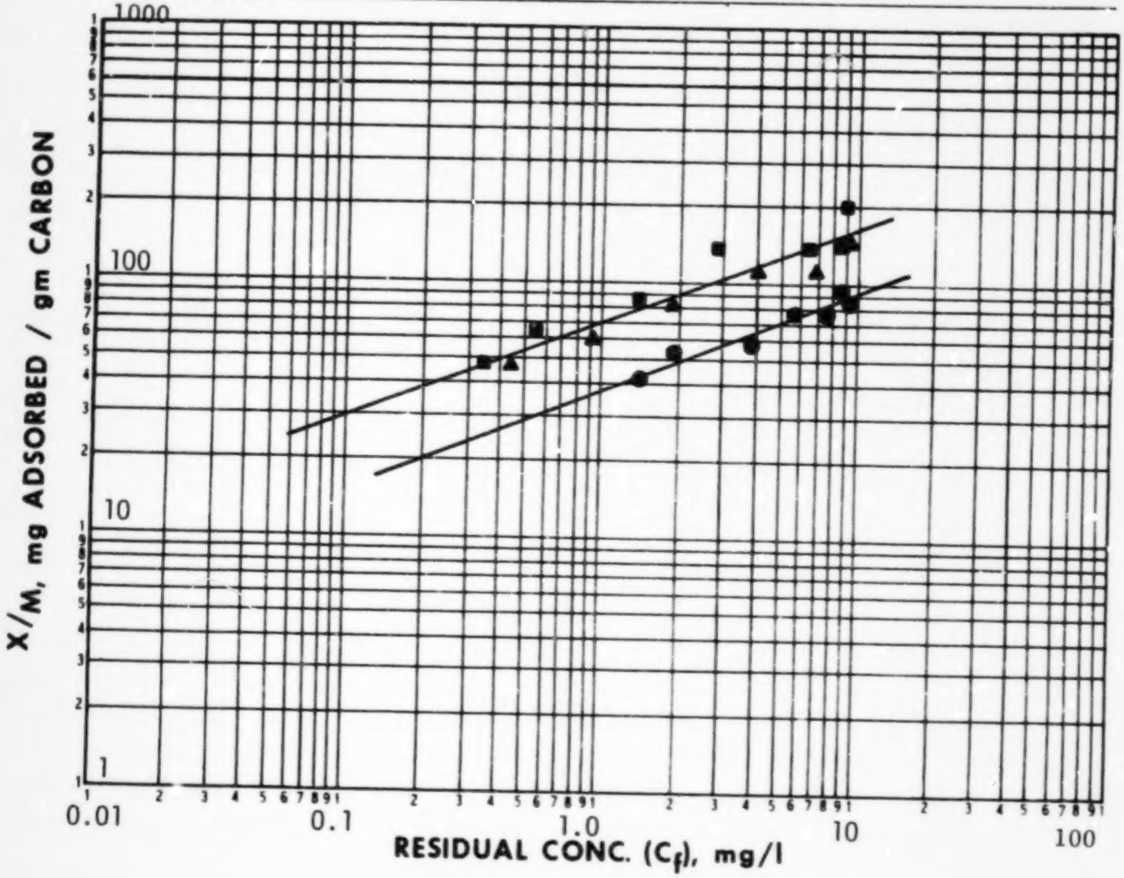
C_o, mg/l	
1.0	14
0.1	3.4
0.01	0.8

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 261 nm

REMARKS:

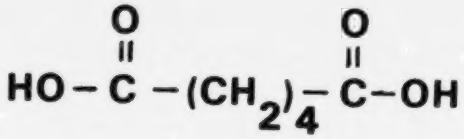
COMPOUND: Adenine



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	9.88			10.00			9.94		
5	9.45	0.43	86	9.00	1.00	200	9.14	0.80	160
10	8.94	0.94	94	8.42	1.58	158	8.42	1.52	152
25	7.92	1.96	78	6.41	3.59	144	6.91	3.03	121
50	5.93	3.95	79	2.91	7.09	142	4.00	5.94	119
100	3.98	5.90	59	1.42	8.58	86	1.89	8.05	81
150	1.97	7.91	53	0.55	9.45	63	0.91	9.03	60
200	1.50	8.38	42	0.34	9.66	48	0.43	9.51	48

COMPOUND: Adipic acid

STRUCTURE:



$$HO-\overset{O}{\overset{\|}{C}}-(CH_2)_4-\overset{O}{\overset{\|}{C}}-OH$$

FORMULA: $C_6H_{10}O_4$ **MOL. WT.** 146.14

FREUNDLICH PARAMETERS	pH		
	3.0		
K	20		
1/n	0.47		
Corr. Coef. r	0.60		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	59		
1.0	20		
0.1	6.9		
0.01	2.4		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	130	430	1300
0.1		39	130
0.01			12

GRANULAR CARBON COLUMN

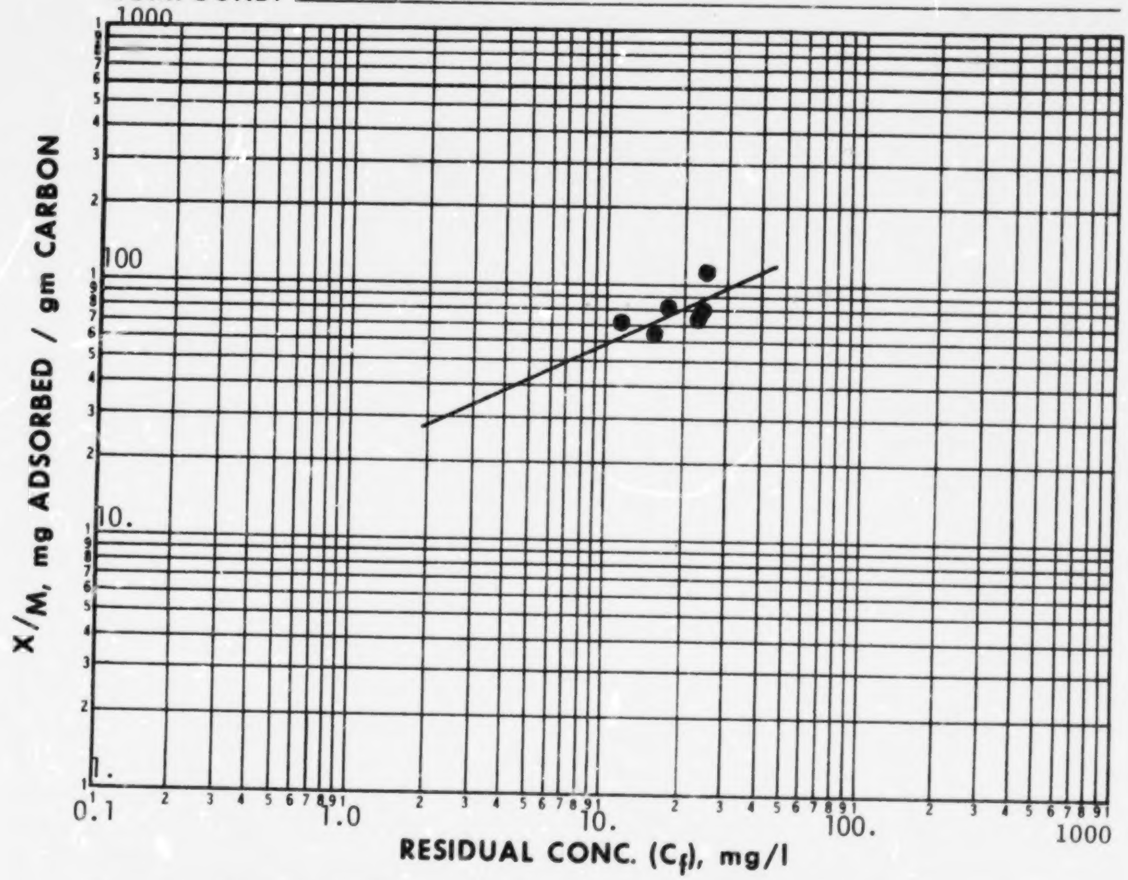
C_o, mg/l	
1.0	50
0.1	15
0 01	4.2

(a) Carbon doses in mg/l at pH. 3

ANALYTICAL METHOD: Total Organic Carbon

REMARKS:

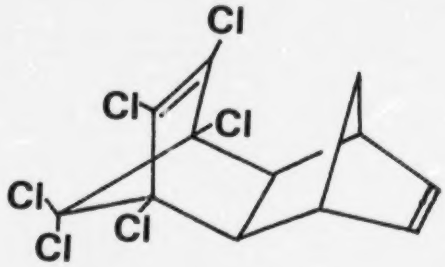
COMPOUND: Adipic Acid



	● pH= 3.0			pH= 7.00			pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	26.4			26.4			26		
10	25.2	1.20	120	27.2			24		
25	24.4	2.00	80	25.2			25.6		
50	22.7	3.70	74	24.0			24.8		
100	18.3	8.10	81	25.2			24.4		
150	16.7	9.70	64.7	21.6			24.4		
200	12.2	14.2	71	23.6			22.8		

COMPOUND: Aldrin

STRUCTURE:



FORMULA: $C_{12}H_8Cl_6$ **MOL. WT.** 365.0

FREUNDLICH PARAMETERS	pH		
	5.3		
K	651		
1/n	0.92		
Corr. Coef. r	0.97		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	651		
0.1	79		
0.01	9.5		
0.001	1.2		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_o, mg/l	C_f, mg/l 0.1	0.01	0.001
1.0	11	110	880
0.1		9.7	88
0.01			8.0

GRANULAR CARBON COLUMN

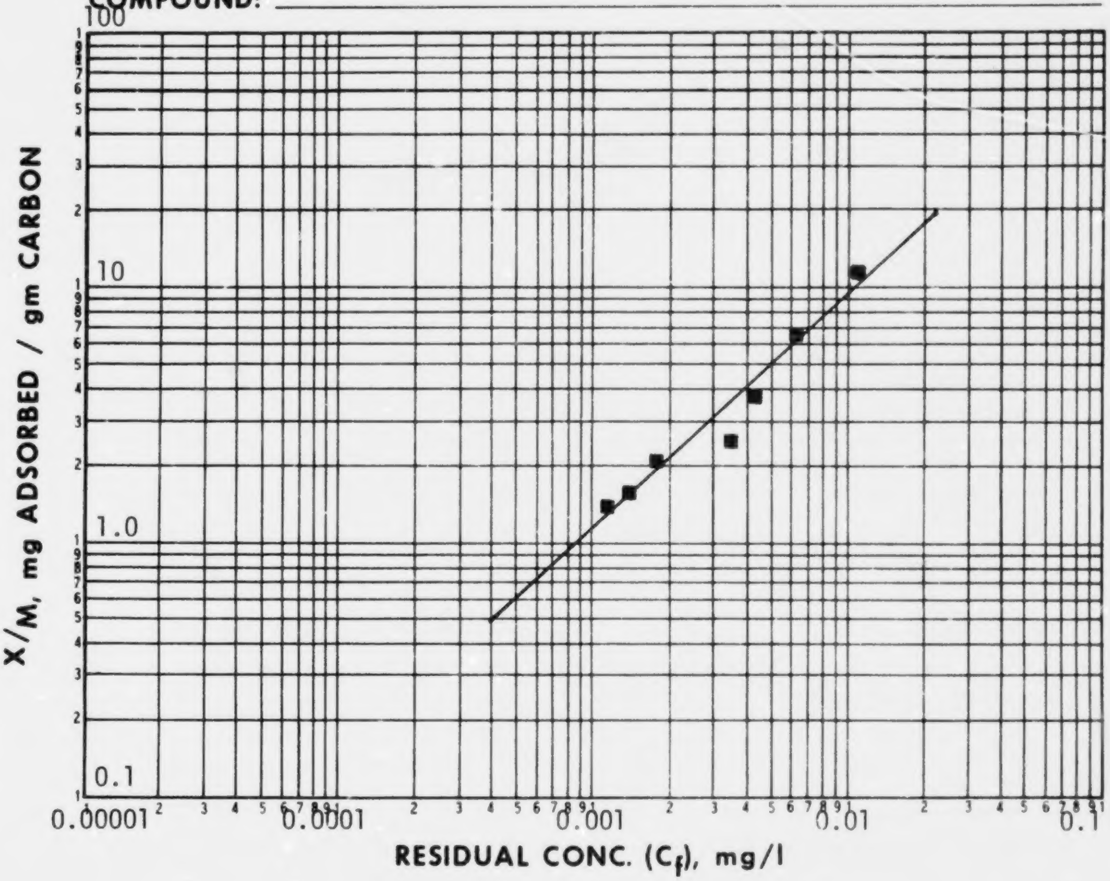
C_o, mg/l	
1.0	1.5
0.1	1.3
0.01	1.1

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent extraction - G.C.

REMARKS:

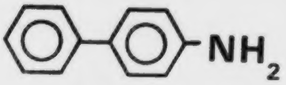
COMPOUND: Aldrin



	● pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	0.023								
1.0	0.011	0.012	12.0						
2.5	0.0061	0.0169	6.76						
5	0.0042	0.0138	3.76						
7.5	0.0035	0.0195	2.60						
10	0.0018	0.0212	2.12						
12.5	0.0014	0.0216	1.73						
15	0.0012	0.0218	1.45						

COMPOUND: 4-Aminobiphenyl

STRUCTURE:



FORMULA: $C_{12}H_{11}N$ **MOL. WT.** 169.12

FREUNDLICH PARAMETERS	pH		
	7.2		
K	200		
1/n	0.26		
Corr. Coef. r	0.96		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	360		
1.0	200		
0.1	110		
0.01	61		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	8.2	16	30
0.1		1.5	3.0
0.01			0.3

GRANULAR CARBON COLUMN

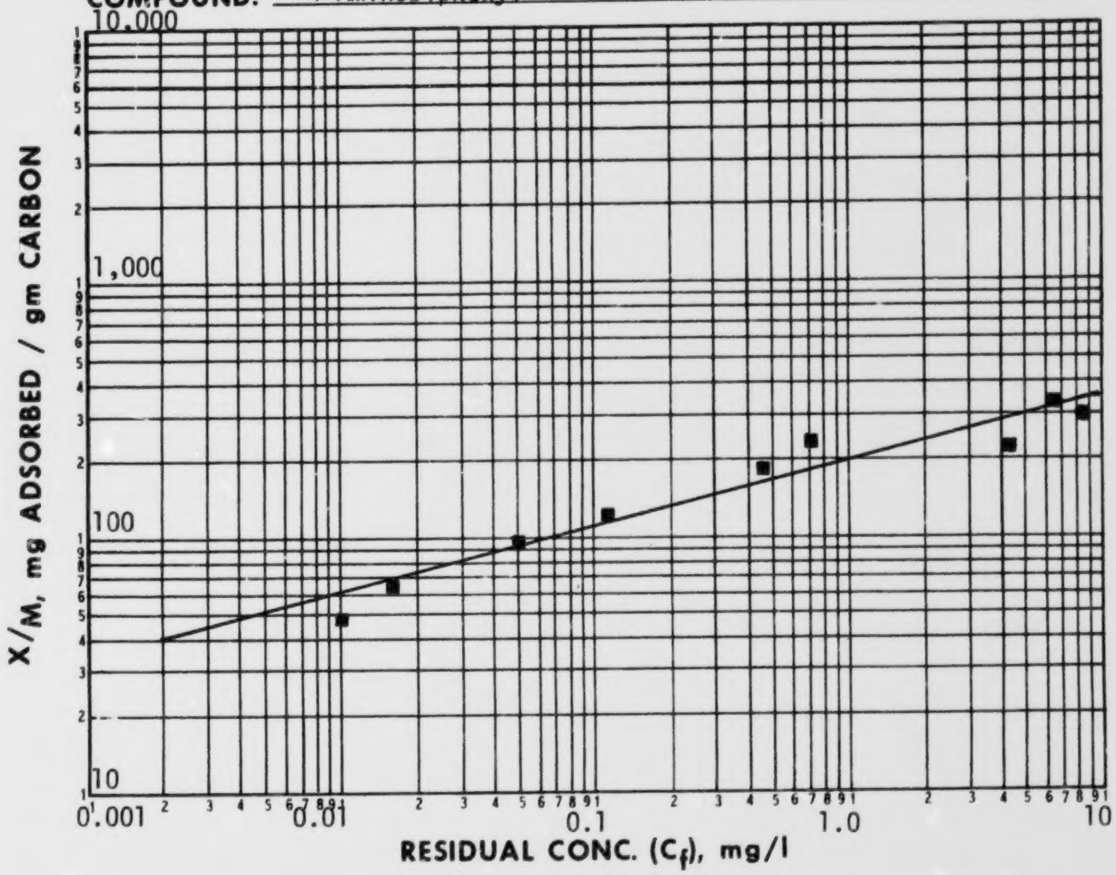
C_o, mg/l	
1.0	5.1
0.1	1.0
0.01	0.2

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 273 nm

REMARKS: OSHA regulated carcinogen

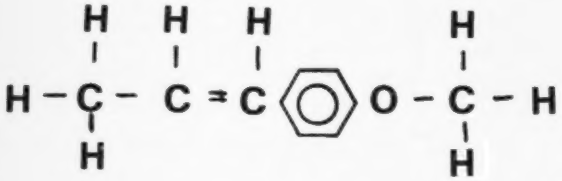
COMPOUND: 4-Aminobiphenyl



	■ pH= 7.2			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	9.80								
5	8.30	1.50	300						
10	6.50	3.30	330						
25	4.20	5.60	224						
37.5	0.70	9.10	243						
50	0.46	9.34	187						
75	0.115	9.69	129						
100	0.05	9.75	98						
150	0.017	9.783	65						
200	0.010	9.79	49						

COMPOUND: Anethole

STRUCTURE:



FORMULA: $C_{10}H_{12}O$ **MOL. WT.** 148

FREUNDLICH PARAMETERS	pH		
	All data pooled		
K	300		
1/n	0.42		
Corr. Coef. r	0.99		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	780		
1.0	300		
0.1	110		
0.01	43		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	8.0	23	61
0.1		2.1	6.1
0.01			0.55

GRANULAR CARBON COLUMN

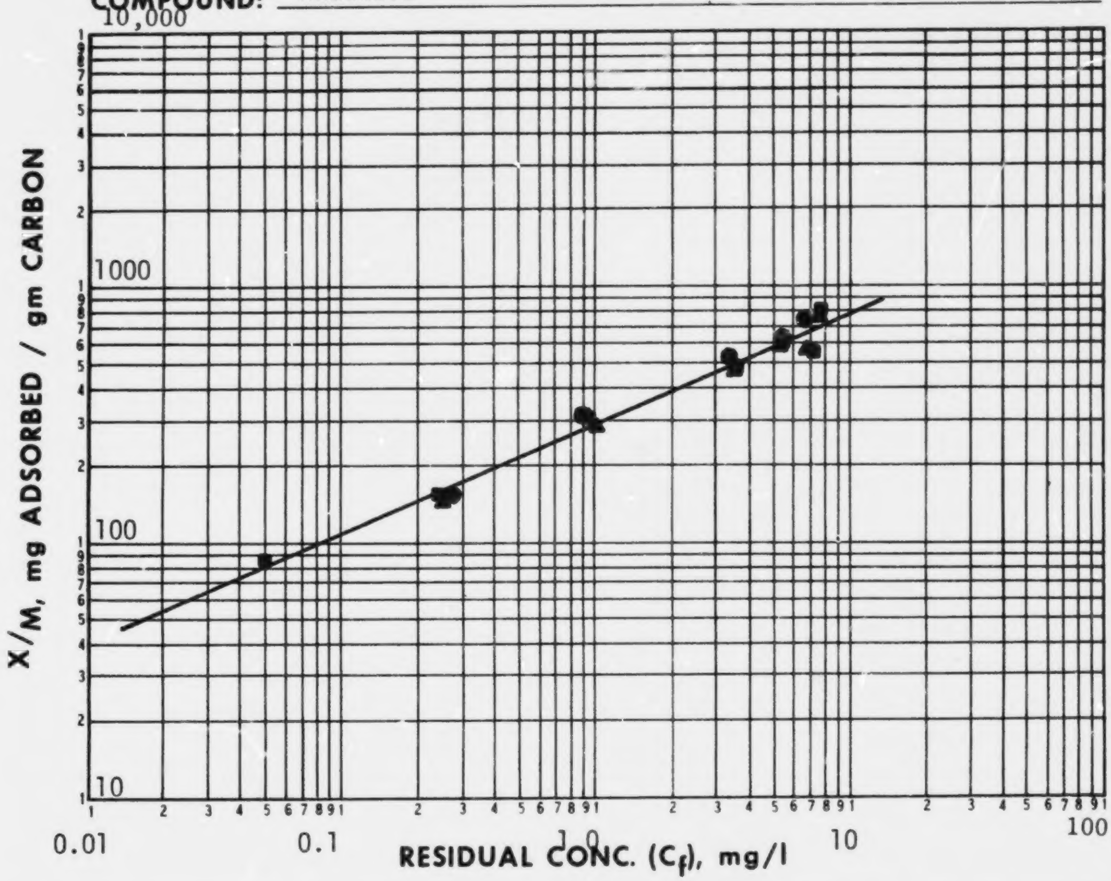
C_o, mg/l	
1.0	3.4
0.1	0.9
0.01	0.2

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 256 nm

REMARKS:

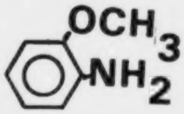
COMPOUND: Anethole



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	8.60			8.55			8.23		
1.0				7.75	0.80	800	7.45	0.78	780
2.5	6.78	1.82	728	7.17	1.38	552	6.78	1.45	580
5.0	5.47	3.13	626	5.55	3.00	600	5.25	2.98	596
10	3.37	5.23	523	3.70	4.85	485	3.50	4.73	473
25	0.90	7.70	308	0.95	7.60	304	1.03	7.20	288
50	0.28	8.32	166	0.23	8.32	166	0.25	7.98	160
100				0.05	8.50	85			

COMPOUND: 0-Anisidine

STRUCTURE:



FORMULA: C_7H_9NO **MOL. WT.** 123.15

FREUNDLICH PARAMETERS	pH		
	3.0	pH 7 and 9 pooled	
K	20	50	
1/n	0.41	0.34	
Corr. Coef. r	0.99	0.99	
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	52	110	
1.0	20	50	
0.1	7.8	23	
0.01	3.0	10	

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	39	95	210
0.1		8.6	21
0.01			1.9

GRANULAR CARBON COLUMN

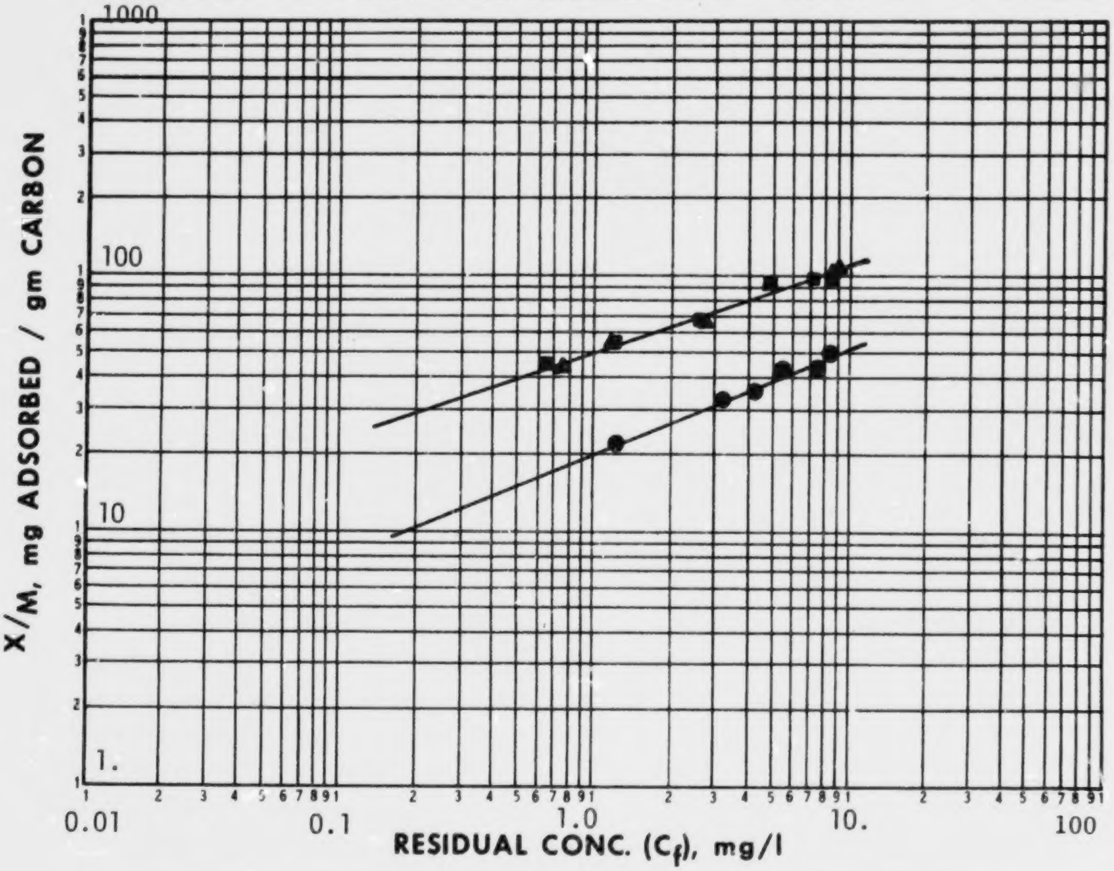
C_o, mg/l	
1.0	20
0.1	4.4
0.01	1.0

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 232 nm

REMARKS:

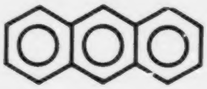
COMPOUND: O-Anisidine



		● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l		C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
pH 3	pH 7 pH 9									
0	0	9.85			9.60			9.55		
10	5							9.00	0.55	110
25	10	8.60	1.25	50	8.65	0.95	95	8.50	1.05	105
50	25	7.70	2.15	43	7.15	2.45	98			
100	50	5.55	4.30	43	4.92	4.68	93	4.85	4.70	94
150	100	4.25	5.60	37	2.68	2.92	69	2.75	6.80	68
200	150	3.23	6.62	33	1.32	8.28	55	1.25	8.30	55
400	200	1.30	8.55	22	0.65	8.95	45	0.75	8.80	44

COMPOUND: Anthracene

STRUCTURE:



FORMULA: $C_{14}H_{10}$ **MOL. WT.** 178.24

FREUNDLICH PARAMETERS	pH		
	5.3		
K	376		
1/n	0.70		
Corr. Coef. r	0.99		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	376		
0.1	75		
0.01	15		
0.001	2.9		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	12	67	340
0.1		6.1	34
0.01			3.1

GRANULAR CARBON COLUMN

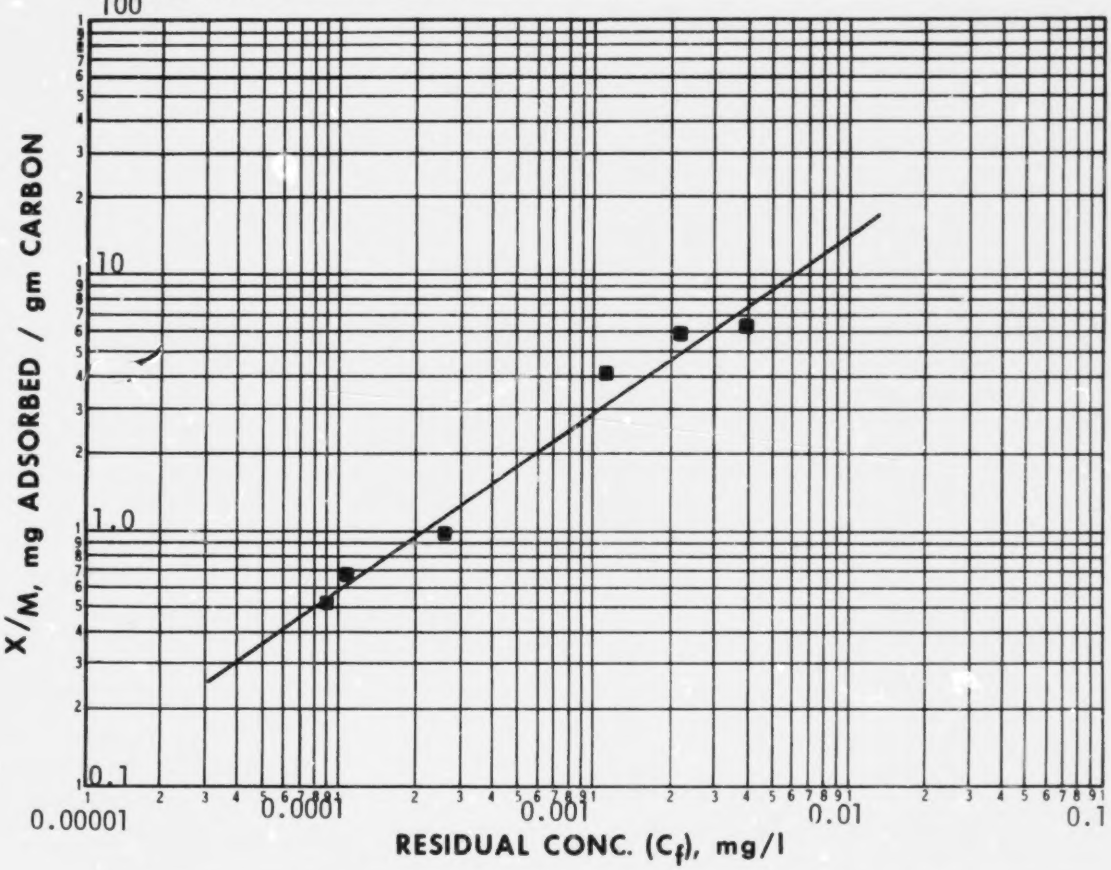
C_o, mg/l	
1.0	2.7
0.1	1.3
0.01	0.7

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent Extraction - G.C.

REMARKS:

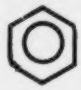
COMPOUND: Anthracene



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	0.00521								
0.2	0.00397	0.00124	6.20						
0.5	0.00222	0.00299	5.98						
1	0.00118	0.00403	4.03						
5	0.00027	0.00494	0.988						
7.5	0.00011	0.00510	0.680						
10	0.00009	0.00512	0.512						

COMPOUND: Benzene

STRUCTURE:



FORMULA: C_6H_6 **MOL. WT.** 78.12

FREUNDLICH PARAMETERS	pH		
	5.3		
K	1.0		
1/n	1.6		
Corr. Coef. r	0.97		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10.0	40		
1.0	1.0		
0.1	0.03		
0.01	0.0007		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON
C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	35,000	>100,000	>100,000
0.1		>100,000	>100,000
0.01			>100,000

GRANULAR CARBON COLUMN

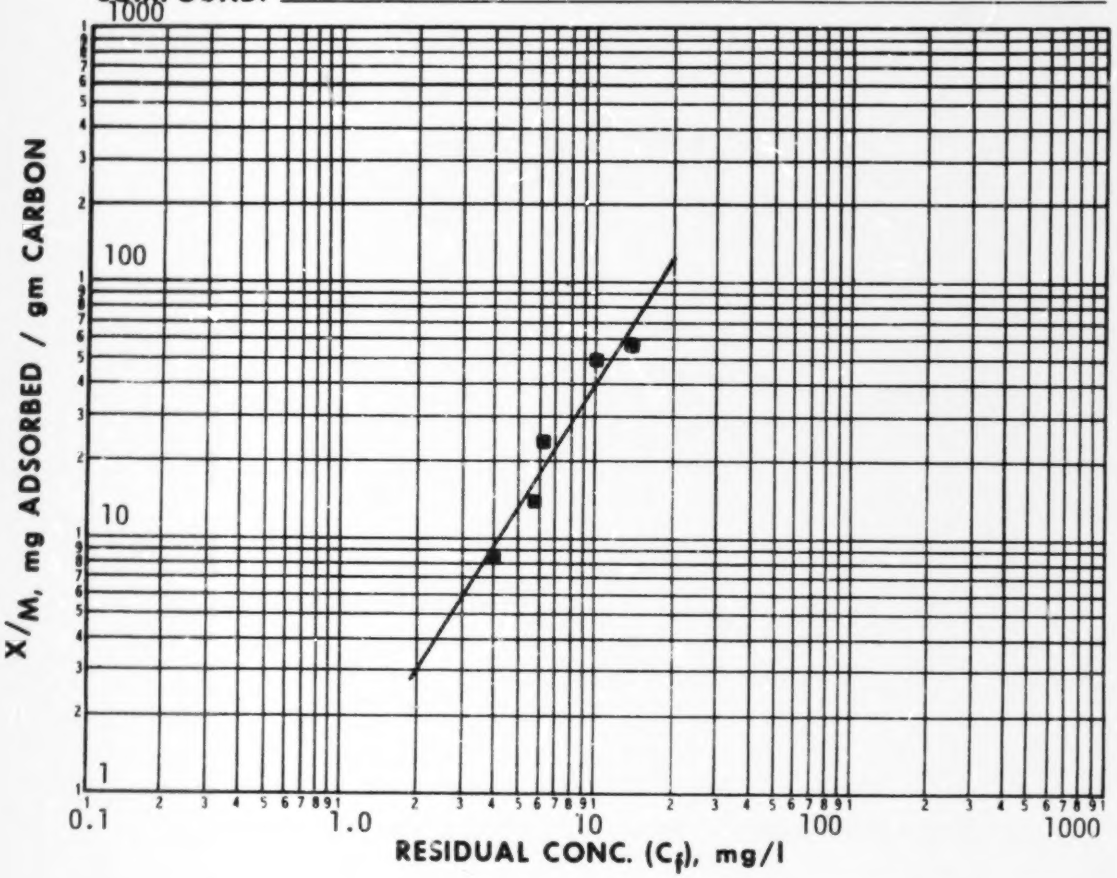
C_o, mg/l	
1.0	980
0.1	4,000
0.01	14,000

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 254.6 nm.

REMARKS:

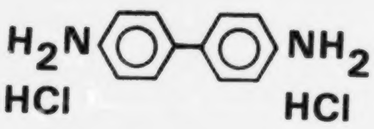
COMPOUND: Benzene



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	19.8								
96	14.2	5.6	58.3						
191	10.3	9.5	49.7						
573	6.2	13.6	23.7						
951	5.8	14.0	14.7						
1910	4.0	15.8	8.3						

COMPOUND: Benzidine dihydrochloride

STRUCTURE:



FORMULA: $C_{12}H_{12}N_2 \cdot 2HCl$ **MOL. WT.** 257.16

FREUNDLICH PARAMETERS	pH		
	3.0	pH 7 and 9 pooled	
K	110	220	
1/n	0.35	0.37	
Corr. Coef. r	0.97	0.97	
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	250	520	
1.0	110	220	
0.1	51	97	
0.01	23	42	

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	9.4	24	58
0.1		2.2	5.7
0.01			0.52

GRANULAR CARBON COLUMN

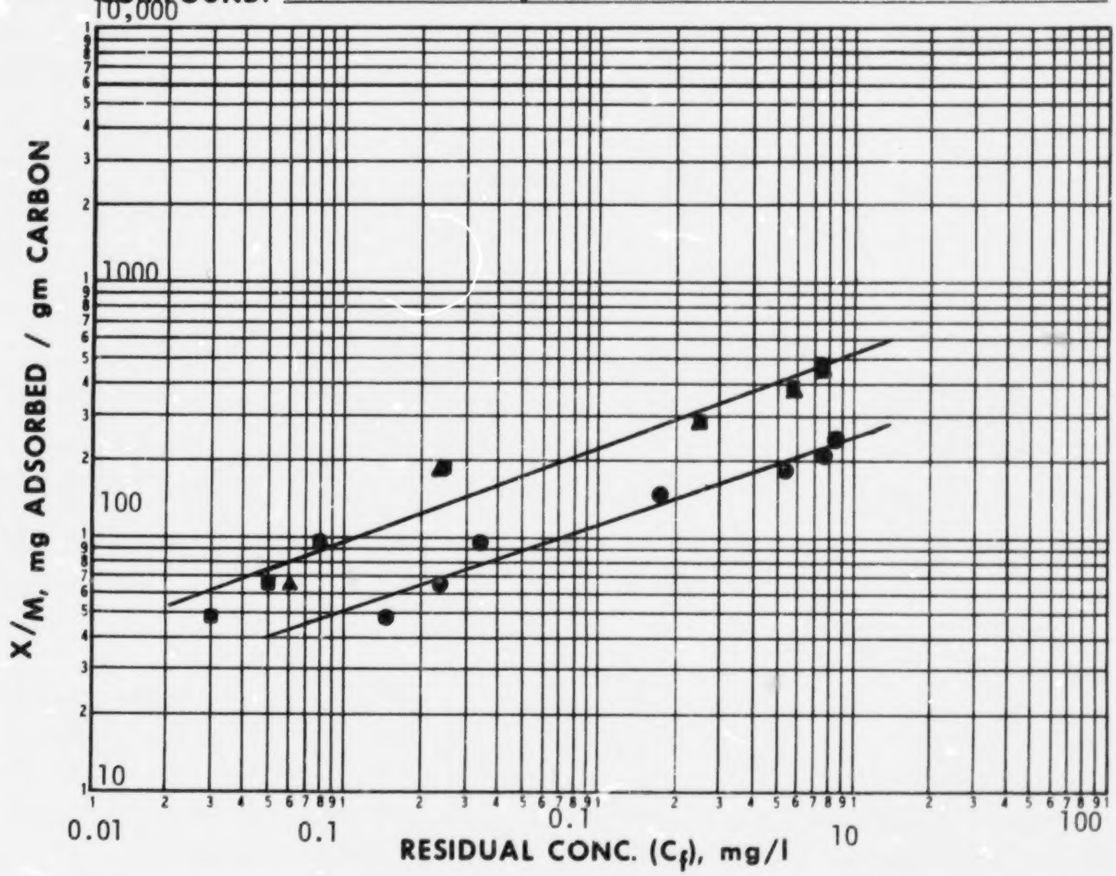
C_o, mg/l	
1.0	4.5
0.1	1.0
0.01	0.2

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 277 nm

REMARKS: OSHA regulated carcinogen.

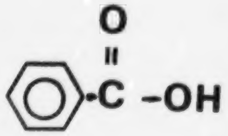
COMPOUND: Benzidine dihydrochloride



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	**C_f**	**$C_o-C_f=X$**	**X/M**	**C_f**	**$C_o-C_f=X$**	**X/M**	**C_f**	**$C_o-C_f=X$**	**X/M**
0	9.99			9.78			9.78		
5	8.73	1.26	252	7.33	2.45	490	7.46	2.32	464
10	7.92	2.07	207	5.83	3.95	395	5.90	3.88	388
25	5.36	4.63	185	2.56	7.22	289	2.54	7.24	290
50	1.80	8.19	164	0.25	9.53	191	0.23	9.55	191
100	0.34	9.65	97	0.08	9.70	97	0.08	9.70	97
150	0.23	9.76	65	0.05	9.73	65	0.06	9.72	65
200	0.16	9.83	49	0.03	9.75	49			

COMPOUND: Benzoic acid

STRUCTURE:



FORMULA: $C_7H_6O_2$ **MOL. WT.** 122.12

FREUNDLICH PARAMETERS	pH		
	3.0	7.0	9.0
K	51	0.76	0.0008
1/n	0.42	1.8	4.3
Corr. Coef. r	0.99	0.91	0.86
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	130	54	21
1.0	51	0.76	0.0008
0.1	19	0.01	-
0.01	7.3	0.0002	-

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	85,000	> 100,000	> 100,000
0.1		> 100,000	> 100,000
0.01			> 100,000

GRANULAR CARBON COLUMN

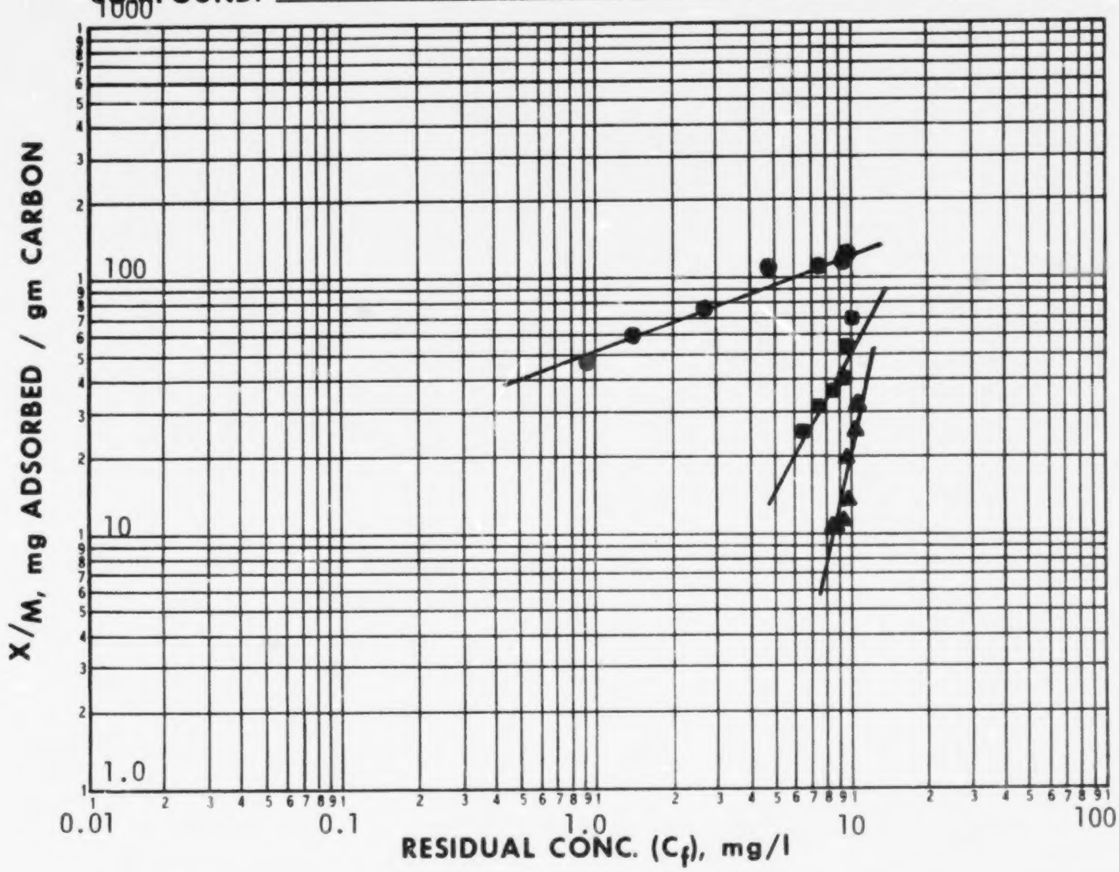
C_o, mg/l	
1.0	1,300
0.1	9,300
0.01	67,000

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 223 nm

REMARKS:

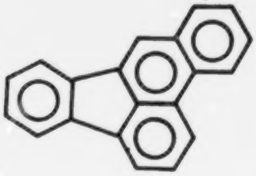
COMPOUND: Benzoic acid



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	10.45			10.45			10.46		
5	9.79	0.66	132	10.10	0.35	70	10.30	0.16	32
10	9.19	1.26	126	9.92	0.52	53	10.19	0.27	27
25	7.58	2.87	115	9.46	0.99	40	9.95	0.51	20
50	4.85	5.60	112	8.60	1.85	37	9.78	0.68	14
100	2.78	7.67	77	7.36	3.09	31	9.20	1.26	12
150	1.47	8.98	60	6.51	3.94	26	8.83	1.63	11
200	0.92	9.53	48				8.17	2.29	11

COMPOUND: 3,4-Benzofluoranthene (Benzo(b)fluoranthene)

STRUCTURE:



FORMULA: $C_{20}H_{12}$ **MOL. WT.** 252.32

FREUNDLICH PARAMETERS	pH		
	7.0		
K	57.0		
1/n	0.37		
Corr. Coef. r	0.94		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	57		
0.1	24		
0.01	10		
0.001	4.3		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON
C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	37	95	230
0.1		8.7	22
0.01			2.0

GRANULAR CARBON COLUMN

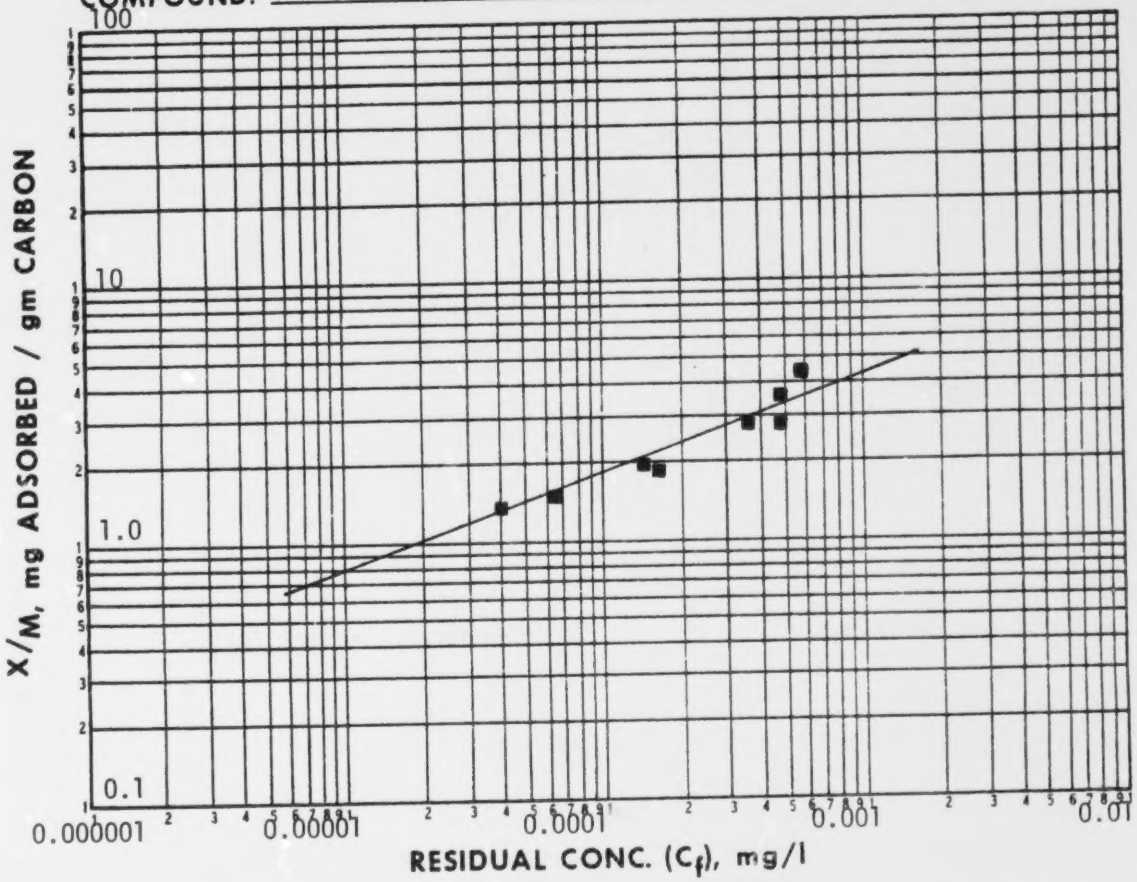
C_o, mg/l	
1.0	18
0.1	4.2
0.01	1.0

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Fluorescence: excitation 298 nm; emission 440 nm.

REMARKS: Modified protocol used for isotherm due to limited solubility.

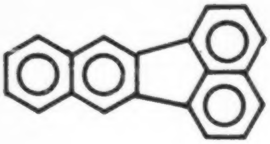
COMPOUND: 3,4-Benzofluoranthene (Benzo(b)fluoranthene)



CARBON DOSE mg/l	$C_o \times 10^3$	$C_f \times 10^3$	$C_o - C_f = X$	X/M
0.14	1.20	0.583	0.000617	4.41
0.14	1.00	0.483	0.000517	3.69
0.29	1.18	0.372	0.000808	2.79
0.29	1.29	0.483	0.000807	2.78
0.43	1.00	0.150	0.000850	1.98
0.43	1.00	0.172	0.000828	1.92
0.72	1.20	0.064	0.001136	1.58
0.81	1.21	0.040	0.001170	1.44

COMPOUND: Benzo(k)fluoranthene

STRUCTURE:



FORMULA: $C_{20}H_{12}$ **MOL. WT.** 252.32

FREUNDLICH PARAMETERS	pH		
	7.1		
K	181		
1/n	0.57		
Corr. Coef. r	0.98		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	180		
0.1	48		
0.01	13		
0.001	3.5		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	18	76	280
0.1		6.7	28
0.01			2.6

GRANULAR CARBON COLUMN

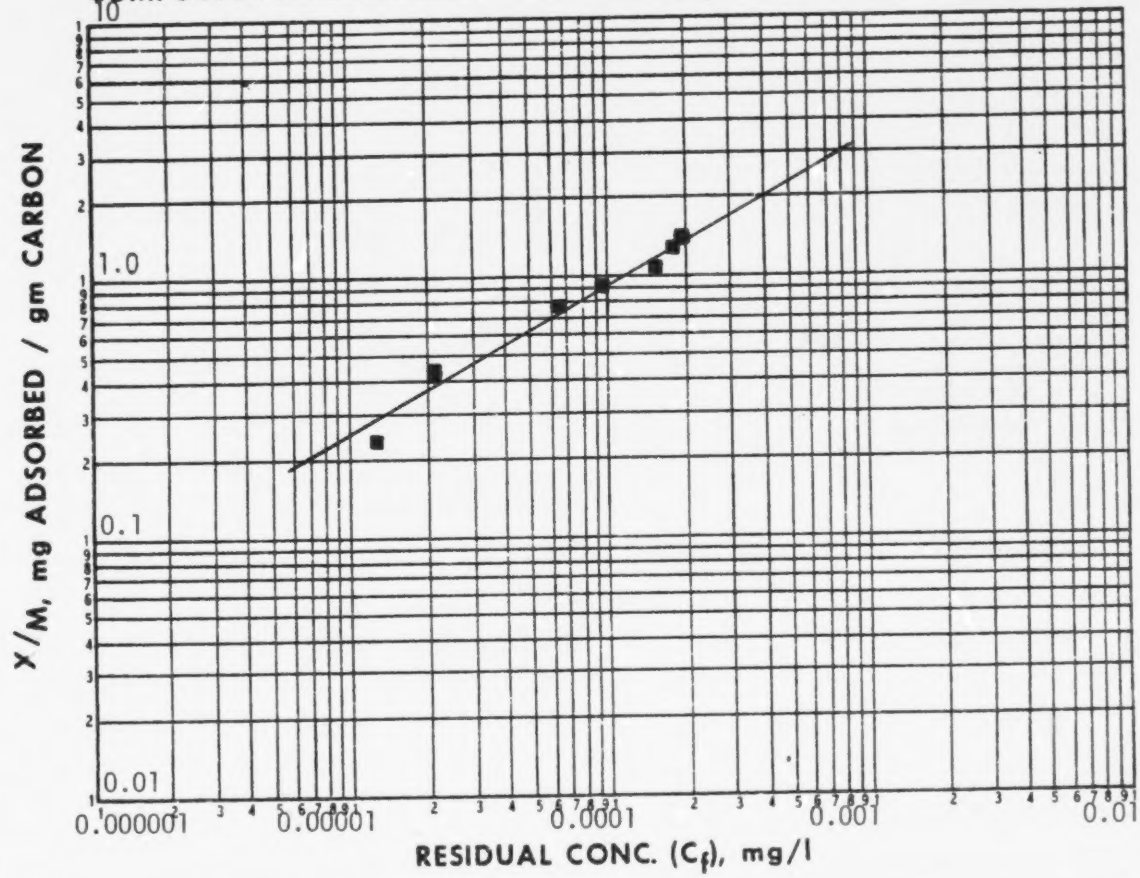
C_o, mg/l	
1.0	5.5
0.1	2.1
0.01	0.8

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Fluorescence; excitation 302 nm; emission 415 nm.

REMARKS: Modified protocol used for isotherm due to limited solubility.

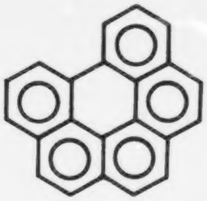
COMPOUND: Benzo(k)fluoranthene



CARBON DOSE mg/l	$C_o \times 10^3$	$C_f \times 10^3$	$C_o - C_f = X$	X/M
0.14	0.397	0.194	0.000203	1.45
0.15	0.377	0.182	0.000195	1.30
0.28	0.471	0.164	0.000307	1.10
0.29	0.358	0.095	0.000263	0.91
0.42	0.391	0.065	0.000326	0.78
0.74	0.349	0.021	0.000328	0.44
0.75	0.337	0.021	0.000316	0.42
1.49	0.365	0.013	0.000352	0.24

COMPOUND: Benzo(ghi)perylene

STRUCTURE:



FORMULA: $C_{22}H_{12}$ **MOL. WT.** 276.34

FREUNDLICH PARAMETERS	pH		
	7.0		
K	10.7		
1/n	0.37		
Corr. Coef. r	0.92		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	10.7		
0.1	4.6		
0.01	2.0		
0.001	0.85		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	200	510	1200
0.1		46	120
0.01			11

GRANULAR CARBON COLUMN

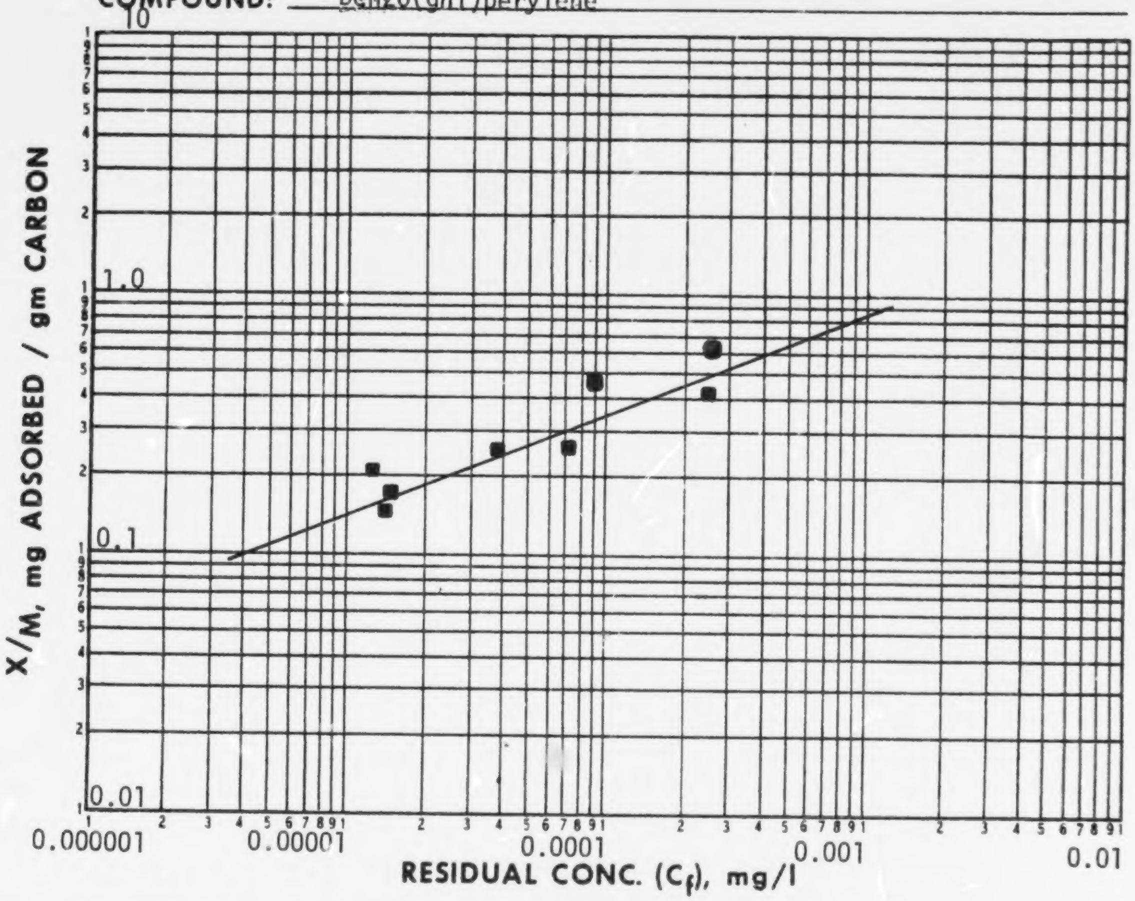
C_o, mg/l	
1.0	93
0.1	22
0.01	5.0

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Fluorescence: excitation 293 nm; emission 418 nm.

REMARKS: Modified protocol used for isotherm due to limited solubility

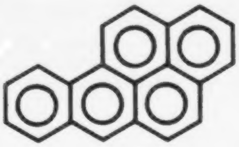
COMPOUND: Benzo(ghi)perylene



CARBON DOSE mg/l	C_o*	C_f*	C_o-C_f=X *	X/M
0.141	0.353	0.267	0.086	0.610
0.143	0.157	0.090	0.067	0.469
0.146	0.306	0.246	0.060	0.411
0.156	0.113	0.071	0.042	0.269
0.308	0.120	0.039	0.081	0.263
0.303	0.076	0.013	0.063	0.208
0.448	0.096	0.016	0.080	0.179
0.454	0.087	0.015	0.072	0.158
*x 10^3				

COMPOUND: Benzo(a)pyrene

STRUCTURE:



FORMULA: $C_{20}H_{12}$ **MOL. WT.** 252.30

FREUNDLICH PARAMETERS	pH		
	7.1		
K	33.6		
1/n	0.44		
Corr. Coef. r	0.90		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	34		
0.1	12		
0.01	4.5		
0.001	1.6		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	74	220	621
0.1		20	62
0.01			5.6

GRANULAR CARBON COLUMN

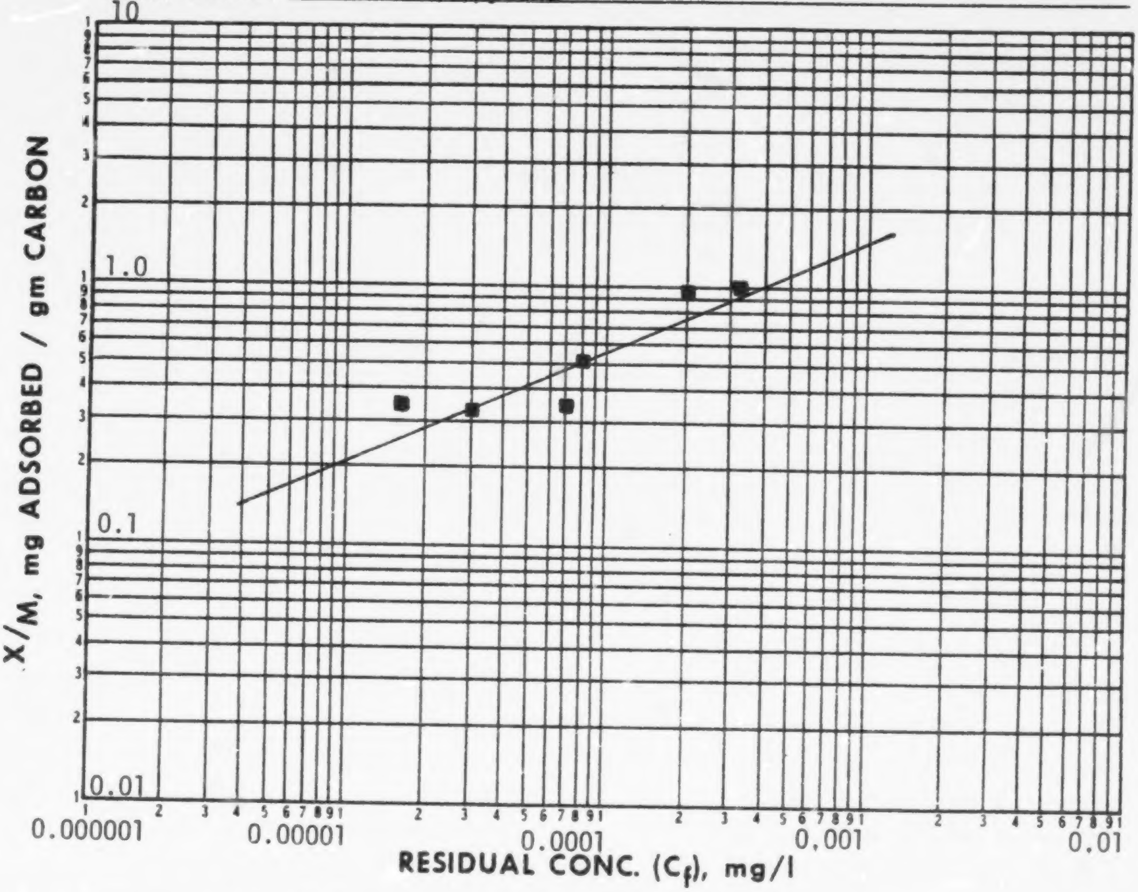
C_o, mg/l	
1.0	29
0.1	8.3
0.01	2.2

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Fluorescence: excitation 298 nm; emission 405 nm.

REMARKS: Modified protocol used for isotherm due to limited solubility.

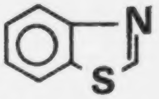
COMPOUND: Benzo(a)pyrene



CARBON DOSE mg/l	$C_o \times 10^3$	$C_f \times 10^3$	$C_o - C_f = X$	X/M
1.2	1.60	0.32	0.00128	1.067
1.2	1.38	0.20	0.00118	0.983
3.9	1.40	0.017	0.00138	0.354
3.9	2.05	0.080	0.00197	0.505
4.0	1.47	0.070	0.00140	0.350
4.0	1.35	0.030	0.00132	0.330

COMPOUND: Benzothiazole

STRUCTURE:



FORMULA: C_7H_5NS **MOL. WT.** 135.19

FREUNDLICH PARAMETERS	pH		
	All data pooled		
K	120		
1/n	0.27		
Corr. Coef. r	0.96		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	230		
1.0	120		
0.1	65		
0.01	35		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	14	28	52
0.1		2.5	5.2
0.01			0.47

GRANULAR CARBON COLUMN

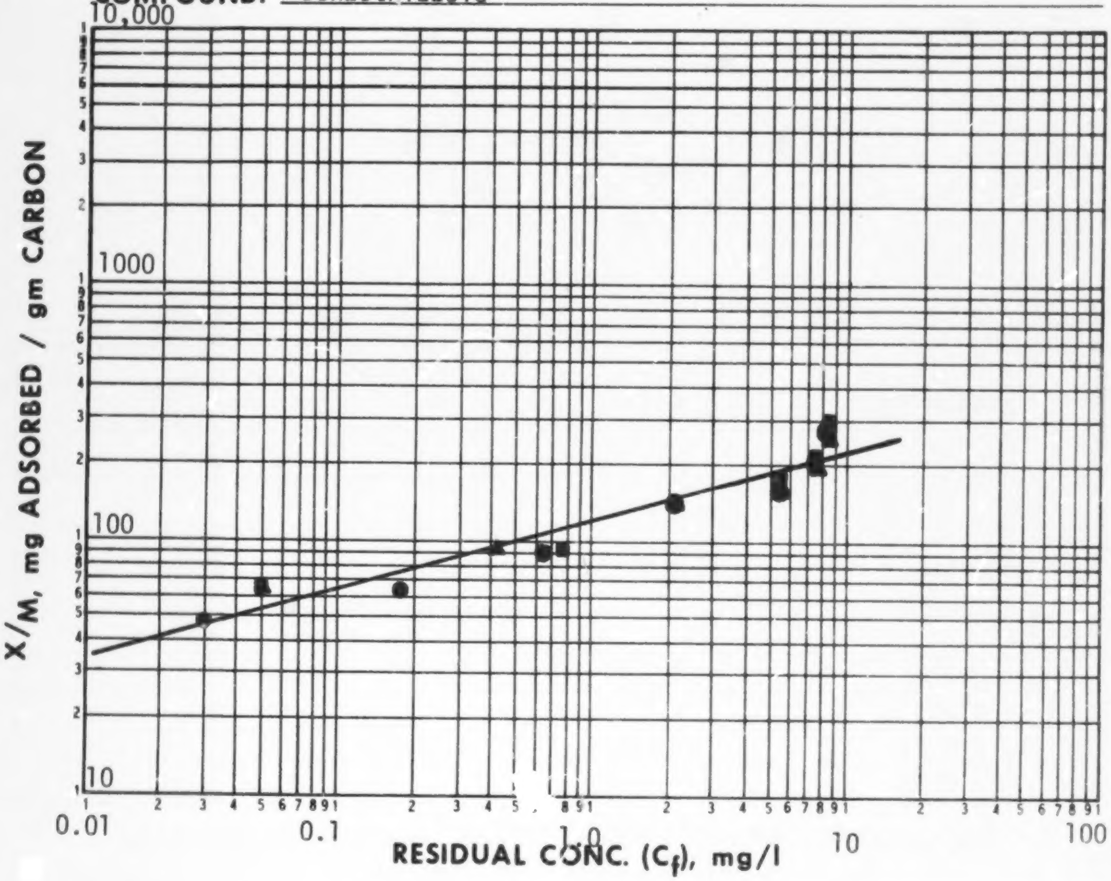
C_o, mg/l	
1.0	8.2
0.1	1.5
0.01	0.3

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 251 nm

REMARKS:

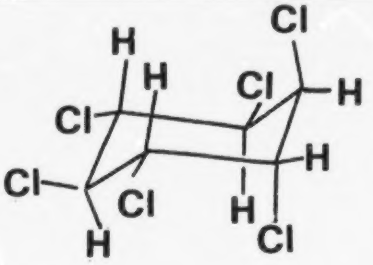
COMPOUND: Benzothiazole



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	9.61			9.85			9.73		
5	8.23	1.38	276	8.35	1.50	300	8.40	1.33	266
10	7.60	2.01	201	7.68	2.17	217	7.75	1.98	198
25	5.42	4.19	168	5.35	4.50	180	5.52	4.21	168
50	2.12	7.49	150	2.17	7.68	154	2.12	7.61	152
100	0.65	8.96	90	0.77	9.08	91	0.41	9.32	93
150	0.18	9.43	63	0.05	9.80	65	0.05	9.68	65
200	0.03	9.58	48						

COMPOUND: α-BHC

STRUCTURE:



FORMULA: $C_6H_6Cl_6$ **MOL. WT.** 290.83

FREUNDLICH PARAMETERS	pH		
	5.4		
K	303		
1/n	0.43		
Corr. Coef. r	0.96		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	303		
0.1	112		
0.01	41		
0.001	15		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	8.0	24	64
0.1		2.2	6.4
0.01			0.6

GRANULAR CARBON COLUMN

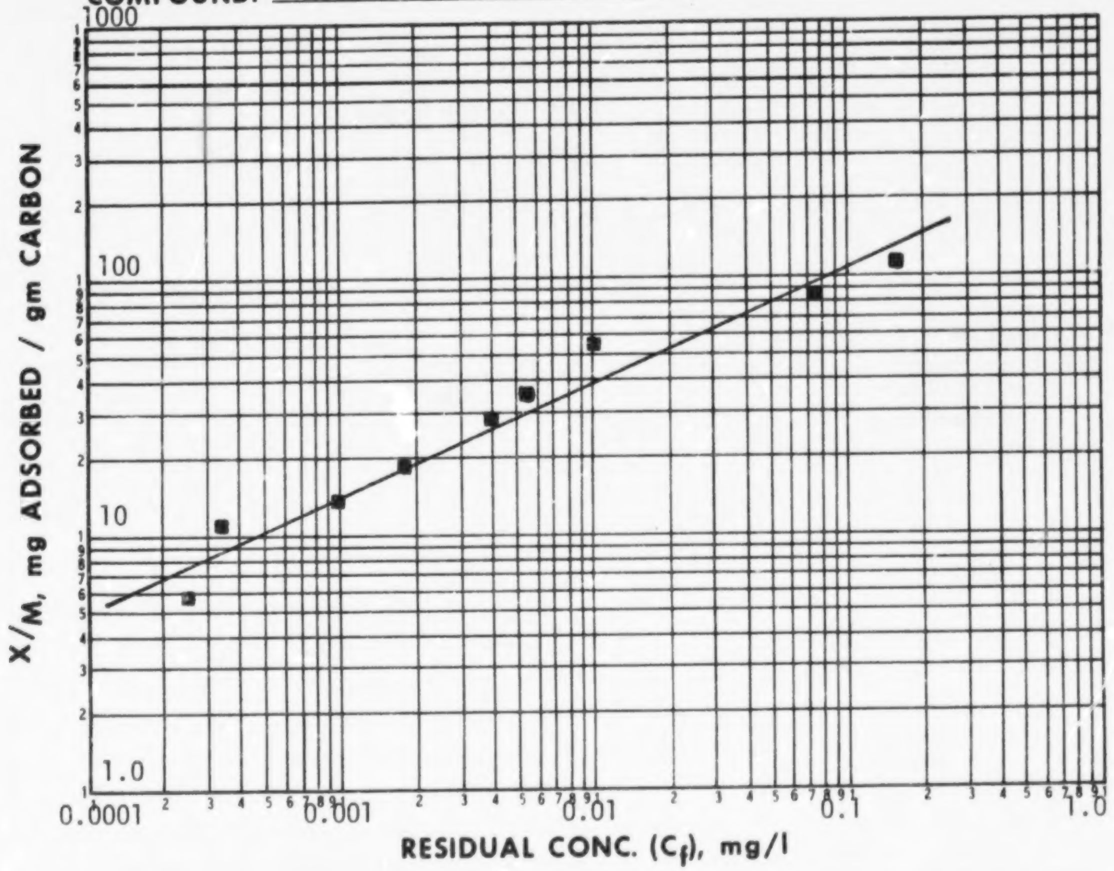
C_o, mg/l	
1.0	3.3
0.1	0.9
0.01	0.2

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent Extraction - G.C.

REMARKS: Isotherm measured using a mixture containing 71% alpha isomer and 29% beta isomer.

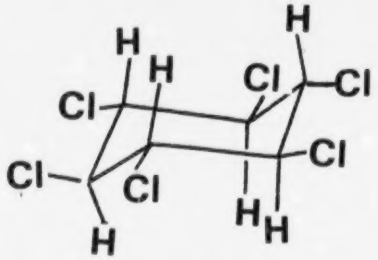
COMPOUND: α-BHC



	■ pH= 5.4			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
	x 10^3								
0	289								
1.0	167	0.122	122						
2.5	75.3	0.214	85.5						
5.0	10.1	0.279	55.8						
7.5	5.28	0.284	37.8						
10	3.97	0.285	28.5						
15	1.83	0.287	19.1						
20	0.99	0.288	14.4						
25	0.33	0.288	11.5						
50	0.25	0.288	5.8						

COMPOUND: β-BHC

STRUCTURE:



FORMULA: $C_6H_6Cl_6$ **MOL. WT.** 290.83

FREUNDLICH PARAMETERS	pH		
	5.4		
K	220		
1/n	0.49		
Corr. Coef. r	0.96		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	220		
0.1	71		
0.01	23		
0.001	7.5		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	13	43	130
0.1		3.9	13
0.01			1.2

GRANULAR CARBON COLUMN

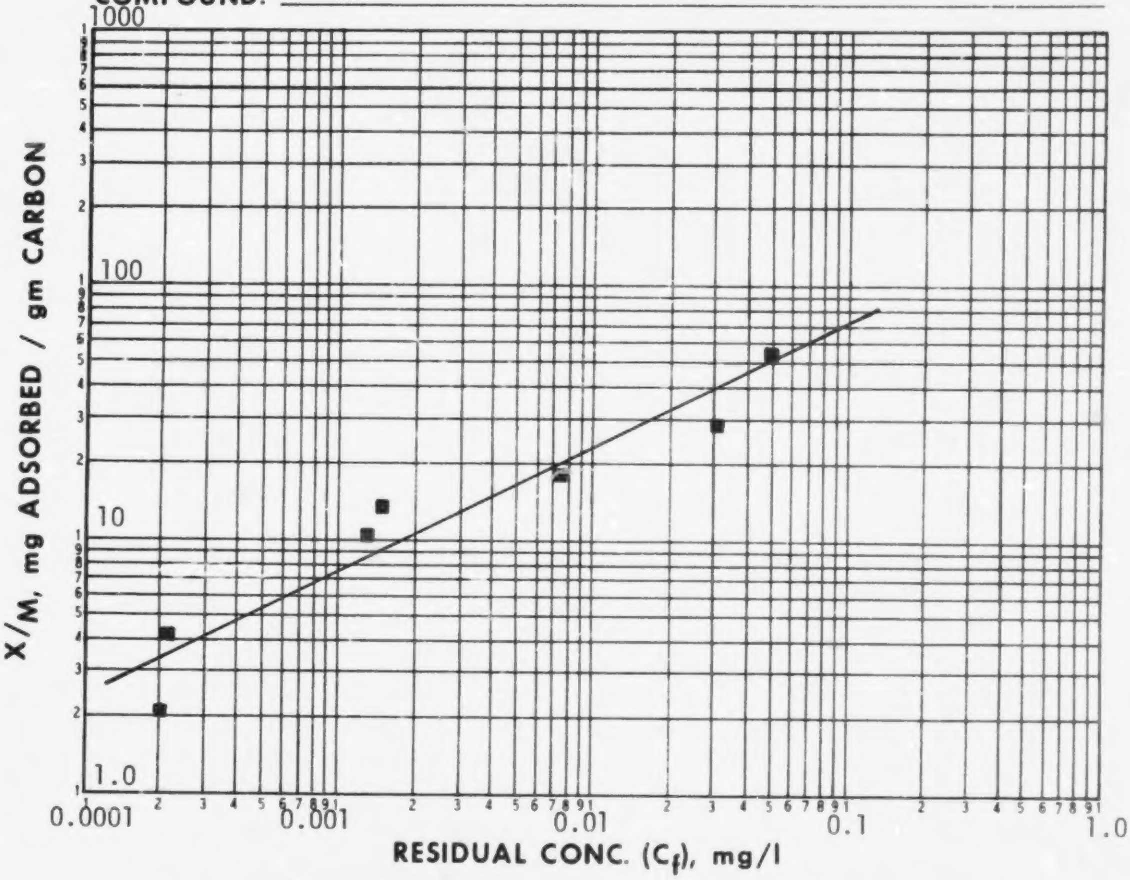
C_o, mg/l	
1.0	4.5
0.1	1.4
0.01	0.4

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent Extraction - G. C.

REMARKS: Isotherm measured using a mixture containing 29% beta isomer and 71% alpha isomer.

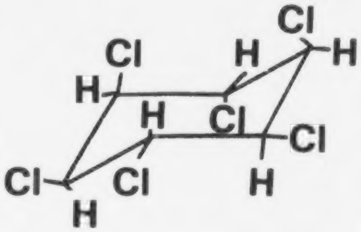
COMPOUND: β-BHC



	■ pH= 5.4			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
	$\times 10^3$								
0	104								
1.0	49.6	0.0544	54.4						
2.5	30.4	0.0736	29.4						
5.0	7.27	0.0967	19.3						
7.5	1.56	0.1024	13.7						
10	1.31	0.1027	10.3						
25	0.22	0.1038	4.15						
50	0.20	0.1038	2.08						

COMPOUND: γ-BHC (Lindane)

STRUCTURE:



FORMULA: $C_6H_6Cl_6$ **MOL. WT.** 290.83

FREUNDLICH PARAMETERS	pH		
	5.3		
K	256		
1/n	0.49		
Corr. Coef. r	0.99		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	256		
0.1	83		
0.01	27		
0.001	8.8		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	11	40	115
0.1		3.4	11
0.01			1.0

GRANULAR CARBON COLUMN

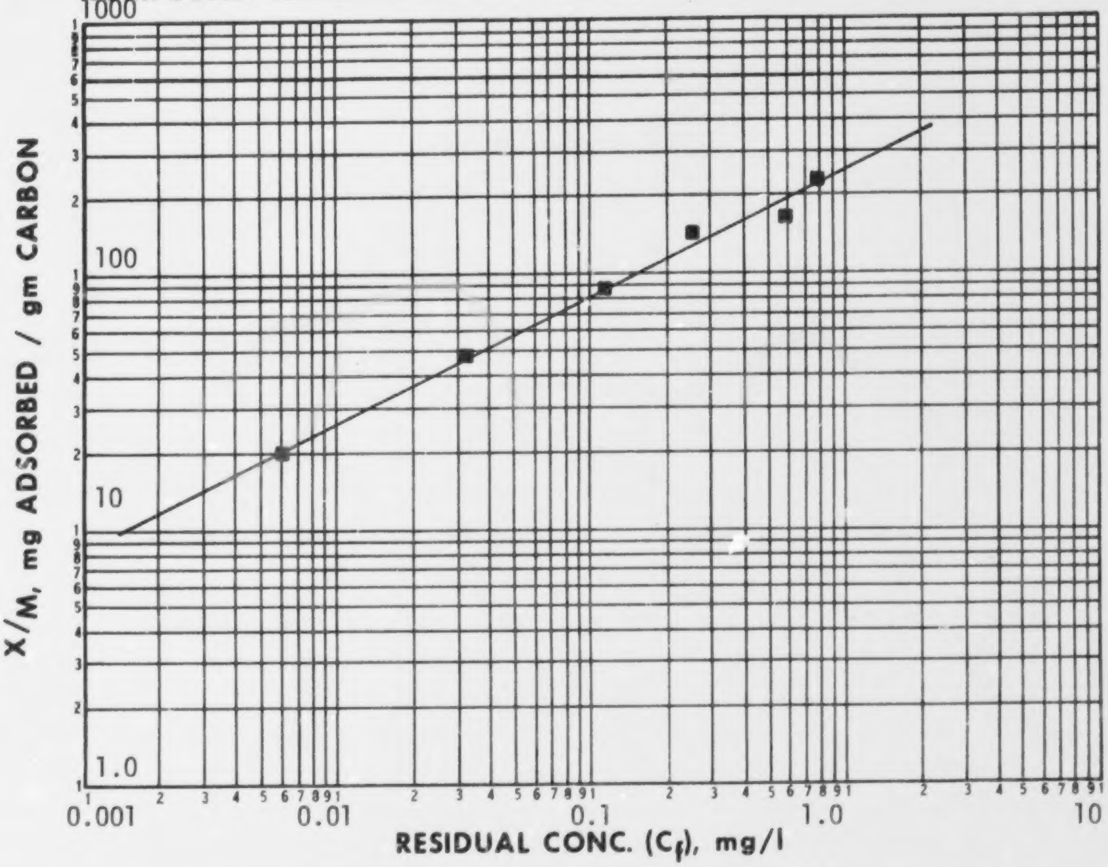
C_o, mg/l	
1.0	3.9
0.1	1.2
0.01	0.4

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent extraction - G. C.

REMARKS:

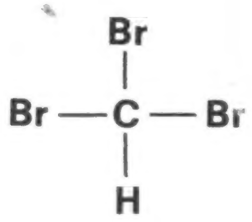
COMPOUND: γ-BHC (Lindane)



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	1.018								
1.0	0.788	0.230	230						
2.5	0.586	0.432	173						
5.0	0.255	0.763	153						
10	0.120	0.898	89.8						
20	0.032	0.986	49.3						
50	0.006	1.012	20.2						

COMPOUND: Bromoform

STRUCTURE:



$$\mathrm{Br-\overset{\overset{Br}{|}}{\underset{\underset{H}{|}}{C}}-Br}$$

FORMULA: $CHBr_3$ **MOL. WT.** 252.75

FREUNDLICH PARAMETERS	pH		
K	19.6		
1/n	0.52		
Corr. Coef. r	0.98		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	19.6		
0.1	5.9		
0.01	1.8		
0.001	0.52		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	150	560	1,900
0.1		51	190
0.01			17

GRANULAR CARBON COLUMN

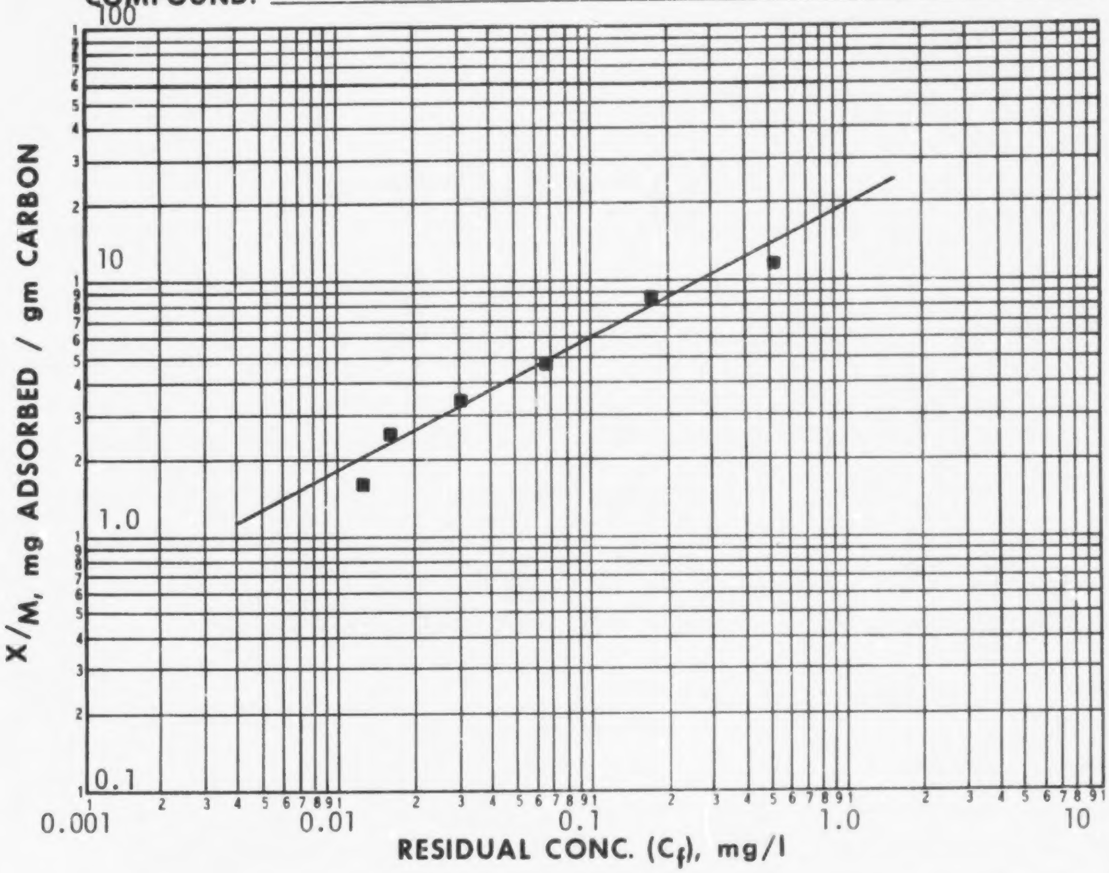
C_o, mg/l	
1.0	51
0.1	17
0.01	5.7

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G. C. Purge and Trap

REMARKS:

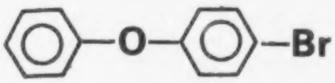
COMPOUND: Bromoform



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	1.000								
38	0.515	0.485	12.6						
96	0.175	0.825	8.58						
192	0.068	0.932	4.85						
289	0.0303	0.970	3.36						
385	0.0172	0.983	2.56						
577	0.0133	0.987	1.71						

COMPOUND: 4-Bromophenyl phenyl ether

STRUCTURE:



FORMULA: $C_{12}H_9OCl$ **MOL. WT.** 249.11

FREUNDLICH PARAMETERS	pH		
	5.3		
K	144		
1/n	0.68		
Corr. Coef. r	0.91		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	144		
0.1	30		
0.01	6.2		
0.001	1.3		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	30	160	770
0.1		14	76
0.01			6.9

GRANULAR CARBON COLUMN

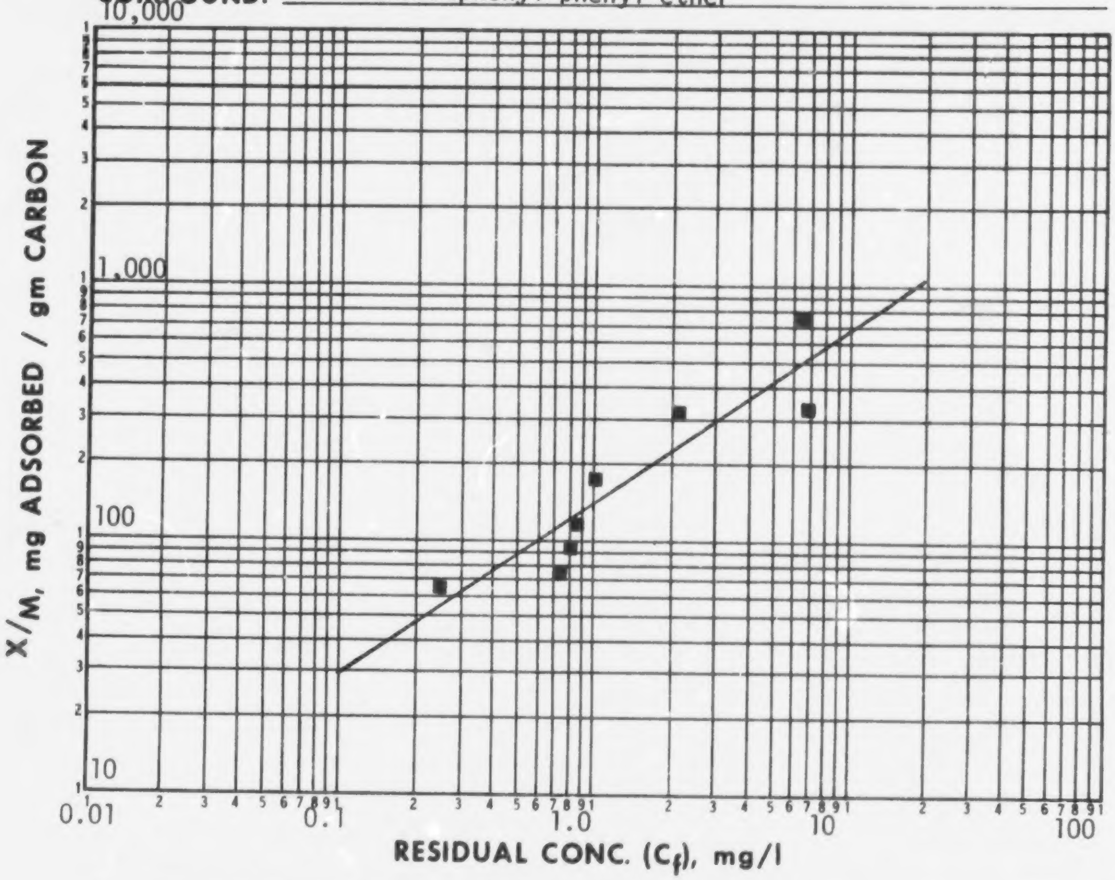
C_o, mg/l	
1.0	7.0
0.1	3.3
0.01	1.6

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 229.5 nm.

REMARKS:

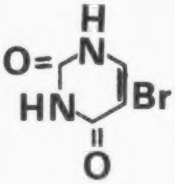
COMPOUND: 4-Bromophenyl phenyl ether



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	10.20								
5	6.36	3.84	768						
10	6.88	3.32	332						
25	2.08	8.12	324.8						
50	1.00	9.20	184						
75	0.84	9.36	124.8						
100	0.80	9.40	94						
125	0.72	9.48	75.8						
150	0.24	9.96	66.4						

COMPOUND: 5-Bromouracil

STRUCTURE:



FORMULA: $C_4H_3N_2O_2Br$ **MOL. WT.** 190.99

FREUNDLICH PARAMETERS	pH		
	pH 3 and 7 pooled	9.0	
K	44	21	
1/n	0.47	0.56	
Corr. Coef. r	0.95	0.86	
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	130	78	
1.0	44	21	
0.1	15	5.8	
0.01	5.1	1.6	

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	60	200	580
0.1		18	58
0.01			5.2

GRANULAR CARBON COLUMN

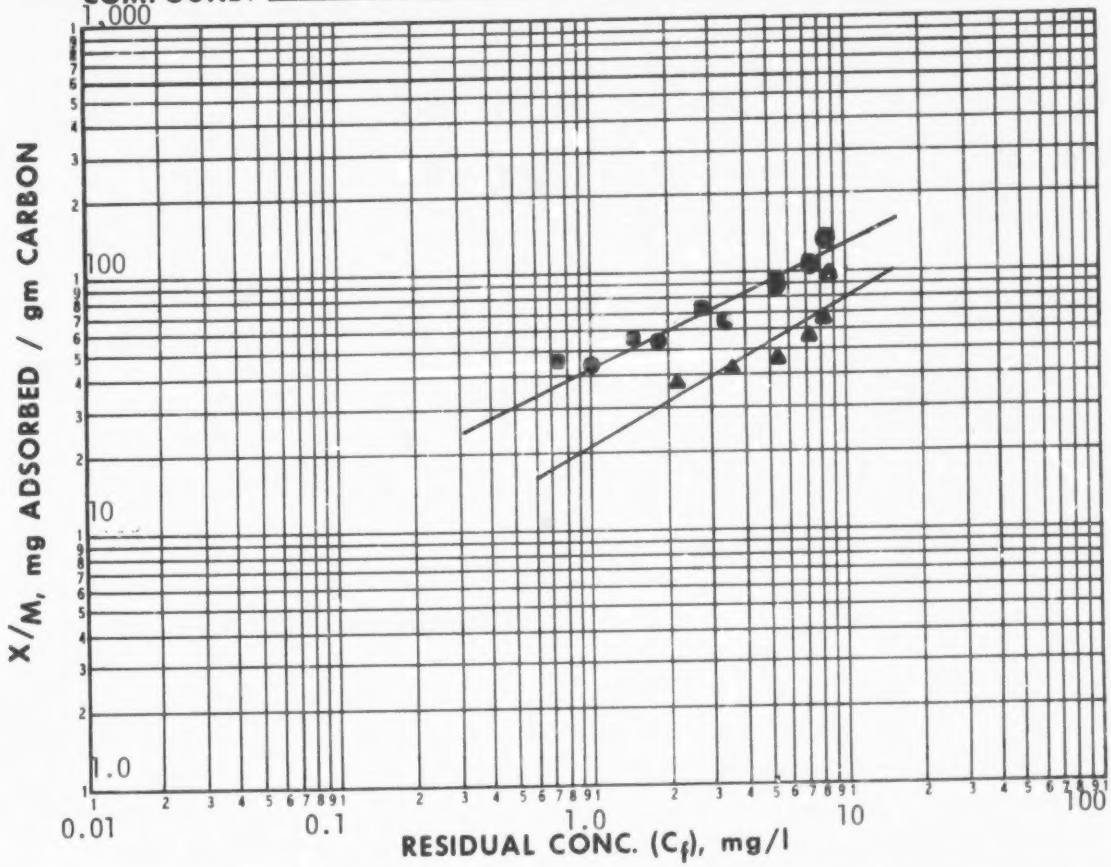
C_o, mg/l	
1.0	23
0.1	6.6
0.01	2.0

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 279 nm

REMARKS:

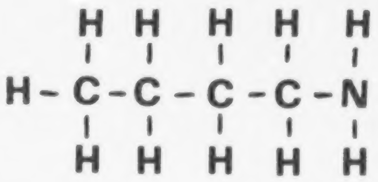
COMPOUND: 5-Bromouracil



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	9.88			9.95			9.89		
10	8.39	1.49	149	8.55	1.40	140	8.91	0.98	98
25	7.27	2.61	104	7.15	2.80	112	8.24	1.65	66
50	5.41	4.47	89	5.34	4.61	92	7.07	2.82	56
100	3.40	6.48	65	2.82	7.13	71	5.29	4.60	46
150	1.91	7.97	53	1.57	8.38	56	3.69	6.20	41
200	1.02	8.86	44	0.73	9.22	46	2.20	7.69	38

COMPOUND: Butylamine

STRUCTURE:



$$H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{N}}$$

FORMULA: $C_4H_{11}N$ **MOL. WT.** 73.14

FREUNDLICH PARAMETERS	pH		
K			
1/n			
Corr. Coef. r			
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l			

GRANULAR CARBON COLUMN

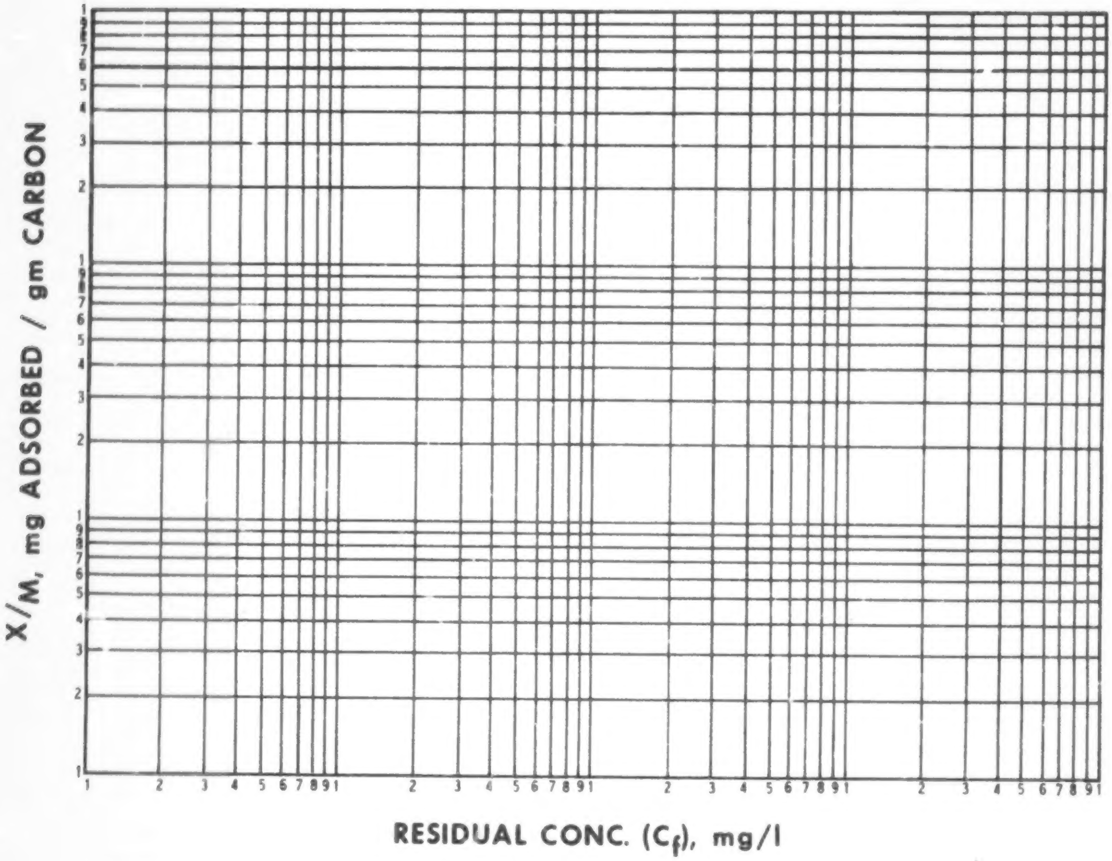
C_o, mg/l	

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Total Organic Carbon

REMARKS: Not adsorbed

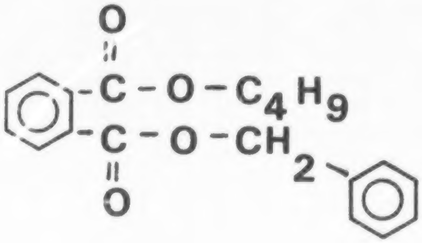
COMPOUND: Butylamine



	pH= 3.0			pH=7.0			pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	18.3			15.8			18.9		
5	16.8			17.4			15.2		
10	17.7			15.5			16.8		
25	16.1			19.8			17.7		
50	15.8			18.6			16.8		
100	16.4			16.1			17.1		
150	17.7			15.5			14.9		
200	15.5			16.1			14.6		

COMPOUND: Butylbenzyl phthalate

STRUCTURE:



FORMULA: $C_{19}H_{20}O_4$ **MOL. WT.** 312.36

FREUNDLICH PARAMETERS	pH		
	5.3		
K	1520		
1/n	1.26		
Corr. Coef. r	0.86		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	1520		
0.1	84		
0.01	4.6		
0.001	0.3		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	11	220	4,000
0.1		20	390
0.01			36

GRANULAR CARBON COLUMN

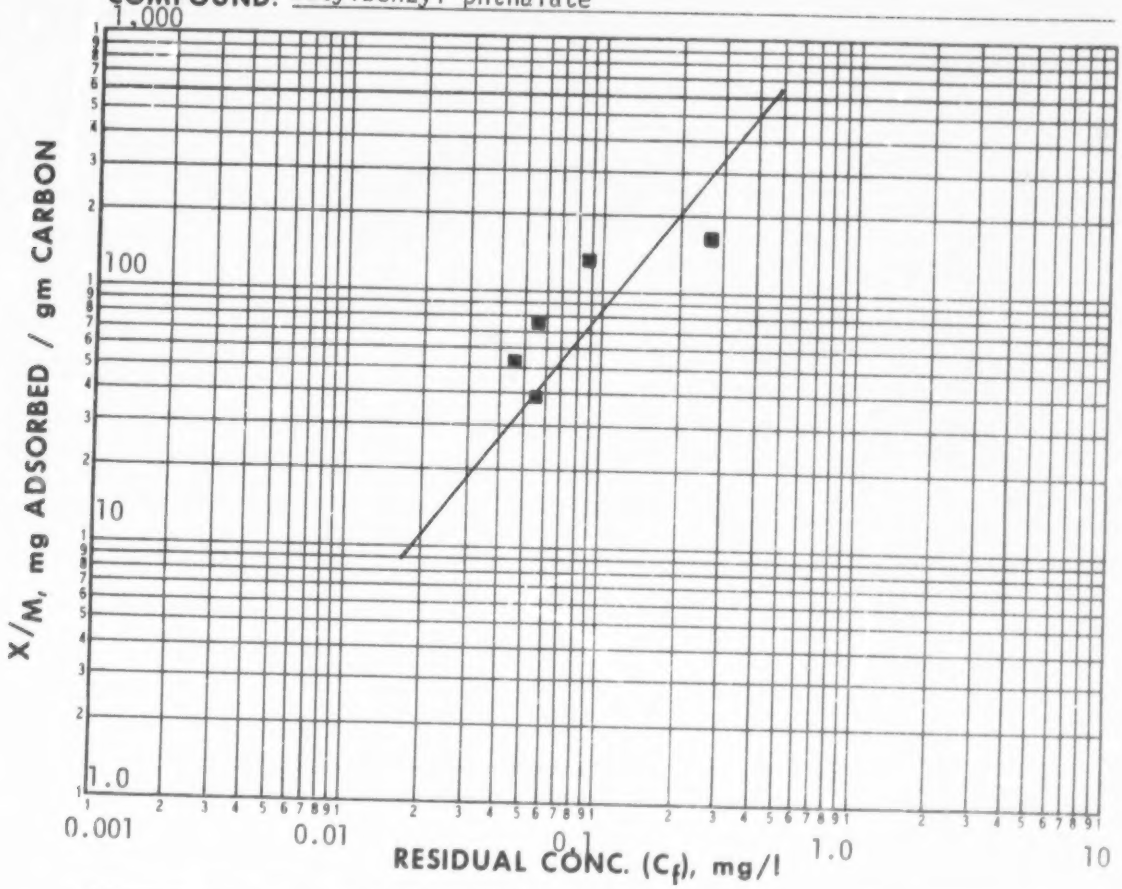
C_o, mg/l	
1.0	0.7
0.1	1.2
0.01	2.2

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent Extraction - G.C.

REMARKS:

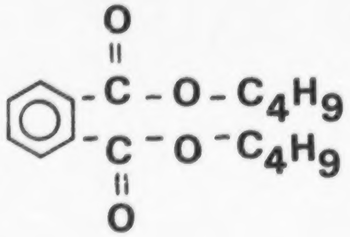
COMPOUND: Butylbenzyl phthalate



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	0.44								
1.0	0.27	0.170	170						
2.5	0.088	0.352	141						
5	0.057	0.383	76.6						
7.5	0.046	0.394	52.5						
20	0.040	0.400	20.0						
30	0.037	0.403	13.4						
40	0.026	0.414	10.4						

COMPOUND: N-Butyl phthalate

STRUCTURE:



FORMULA: $C_{16}H_{22}O_4$ **MOL. WT.** 278.35

FREUNDLICH PARAMETERS	pH		
	3.0		
K	220		
1/n	0.45		
Corr. Coef. r	0.99		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	610		
1.0	220		
0.1	77		
0.01	28		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	12	37	100
0.1		3.3	10
0.01			0.94

GRANULAR CARBON COLUMN

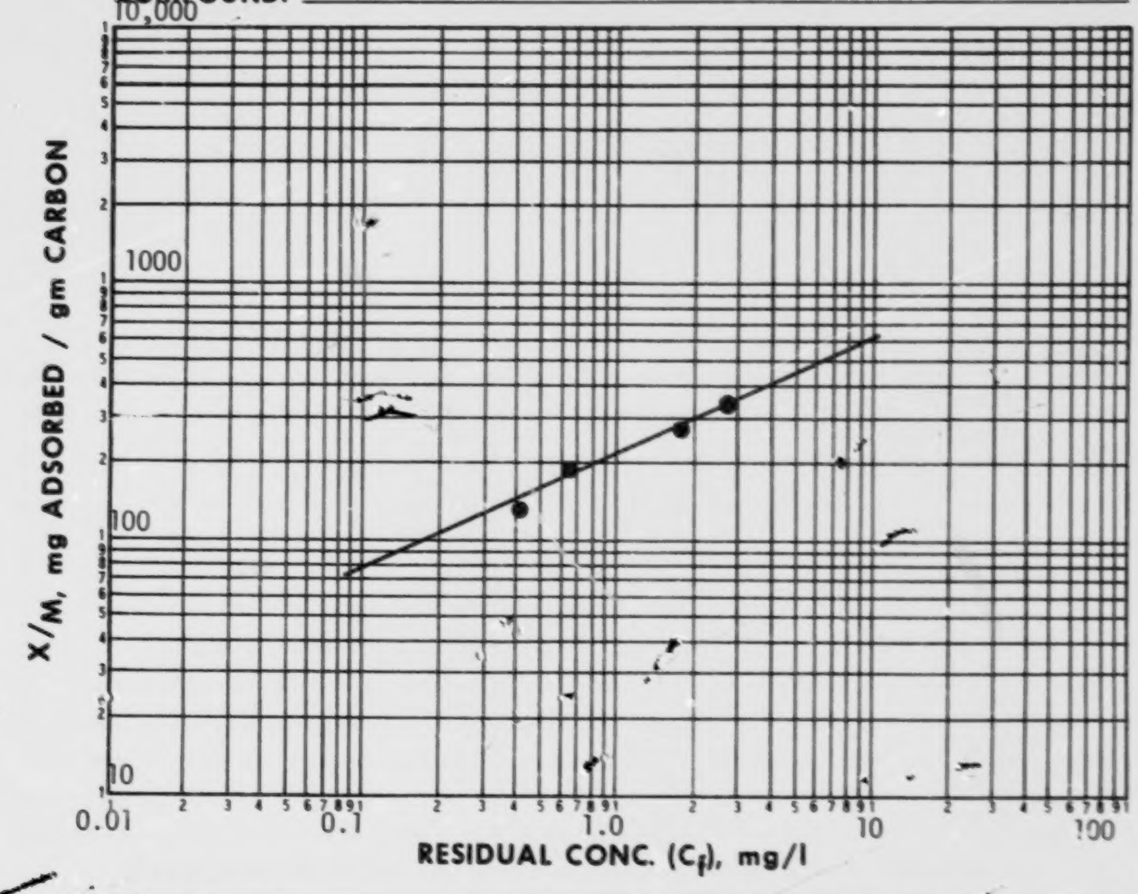
C_o, mg/l	
1.0	4.7
0.1	1.3
0.01	0.4

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 225 nm

REMARKS:

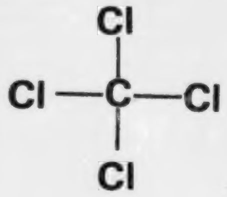
COMPOUND: N-Butyl phthalate



	● pH= 3.0			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	4.54								
5	2.83	1.71	342						
10	1.79	2.75	275						
20	0.67	3.87	194						
30	0.42	4.12	137						

COMPOUND: Carbon tetrachloride

STRUCTURE:



FORMULA: CCl_4 **MOL. WT.** 153.82

FREUNDLICH PARAMETERS	pH		
	5.3		
K	11.1		
1/n	0.83		
Corr. Coeff	0.99		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	11		
0.1	1.6		
0.01	0.24		
0.001	0.04		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	550	4100	28,000
0.1		370	2,800
0.01			250

GRANULAR CARBON COLUMN

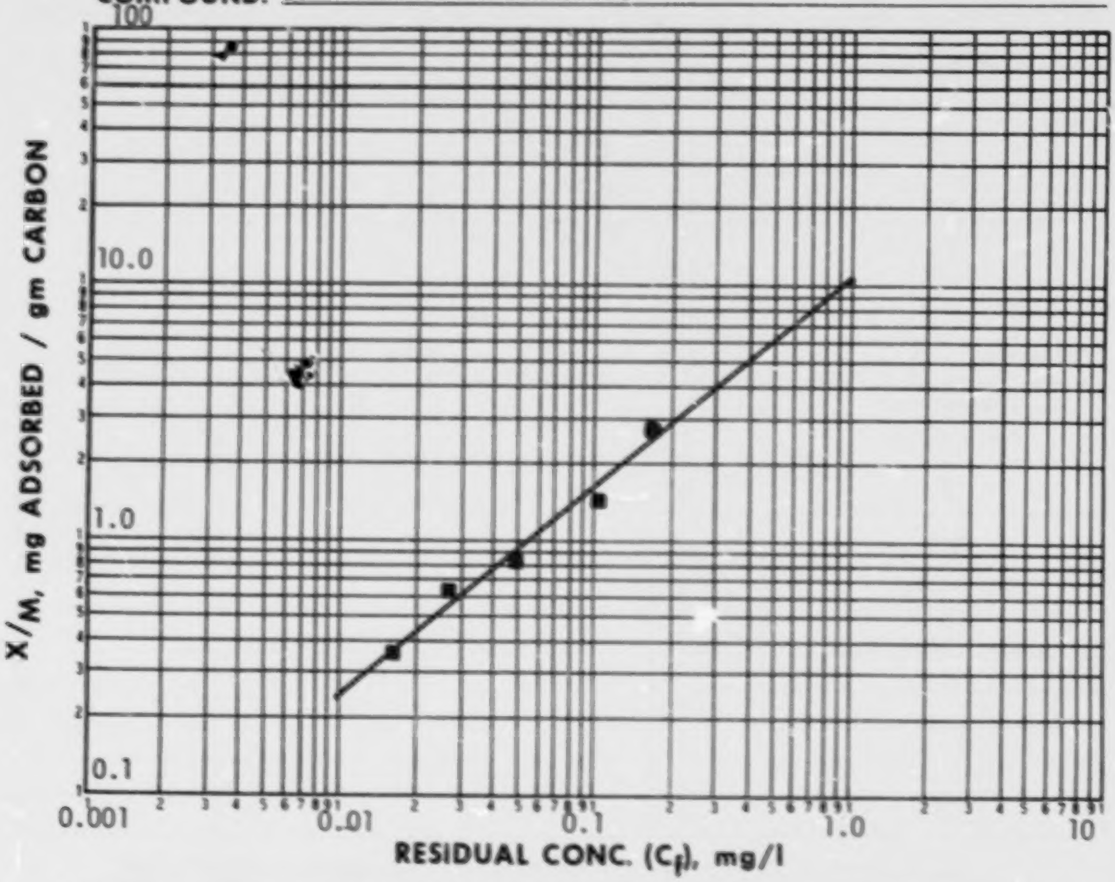
C_o, mg/l	
1.0	90
0.1	61
0.01	42

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G. C. Purge and Trap

REMARKS:

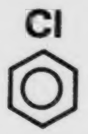
COMPOUND: Carbon tetrachloride



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	1.000								
288	0.177	0.823	2.85						
577	0.104	0.896	1.55						
1154	0.049	0.951	0.824						
1538	0.027	0.973	0.632						
2692	0.0170	0.983	0.365						

COMPOUND: Chlorobenzene

STRUCTURE:



FORMULA: C_6H_5Cl **MOL. WT.** 112.56

FREUNDLICH PARAMETERS	pH		
	7.4		
K	91		
1/n	0.99		
Corr. Coef. r	0.98		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	890		
1.0	91		
0.1	9.3		
0.01	0.95		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	92	970	9,400
0.1		88	930
0.01			84

GRANULAR CARBON COLUMN

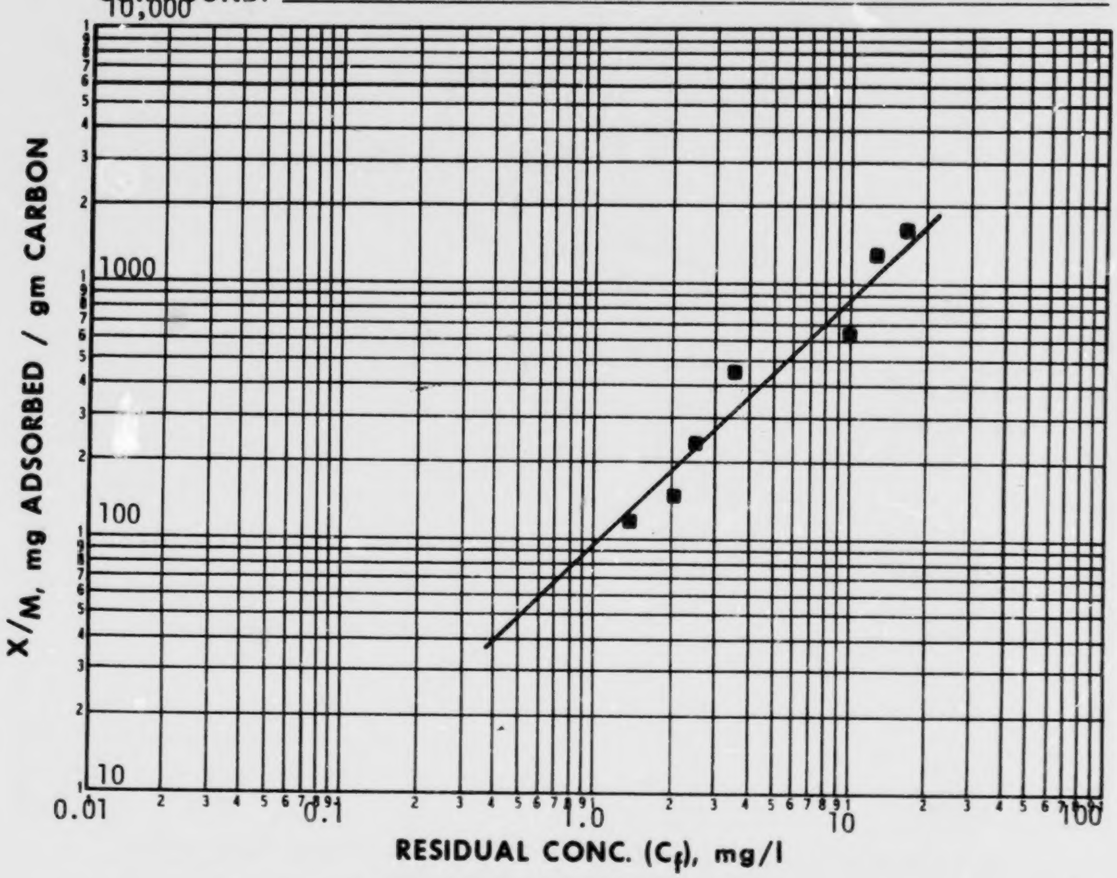
C_o, mg/l	
1.0	11
0.1	11
0.01	11

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 209 nm

REMARKS:

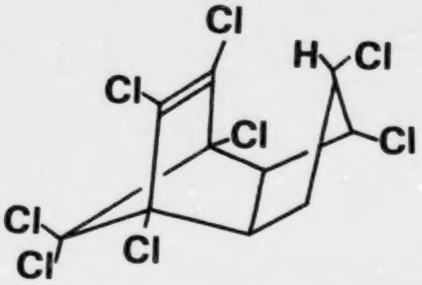
COMPOUND: Chlorobenzene



	■ pH= 7.4			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	25.9								
5	17.4	8.50	1700						
10	13.13	12.77	1277						
25	10.16	15.74	630						
50	3.61	22.29	446						
100	2.49	23.41	234						
150	2.06	23.84	159						
200	1.40	24.5	123						

COMPOUND: Chlordane

STRUCTURE:



FORMULA: $C_{10}H_6Cl_8$ **MOL. WT.** 409.80

FREUNDLICH PARAMETERS	pH		
	5.3		
K	245		
1/n	0.38		
Corr. Coef. r	0.95		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	245		
0.1	102		
0.01	43		
0.001	18		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

	C_f, mg/l		
C_o, mg/l	0.1	0.01	0.001
1.0	8.8	23	56
0.1		2.1	5.6
0.01			0.5

GRANULAR CARBON COLUMN

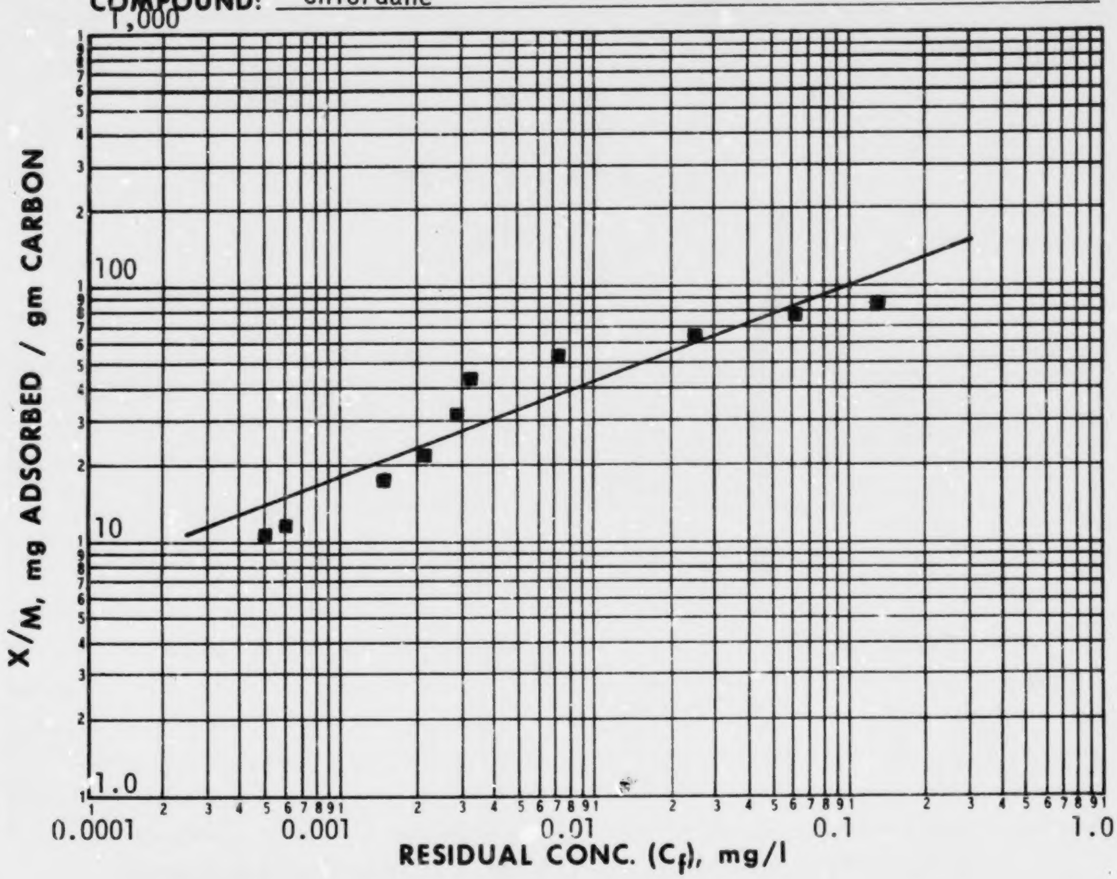
C_o, mg/l	
1.0	4.1
0.1	1.0
0.01	0.2

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent Extraction - G.C.

REMARKS:

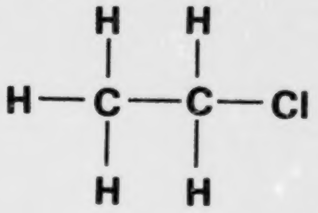
COMPOUND: Chlordane



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	0.219								
1.0	0.132	0.087	87.0						
2.0	0.061	0.158	79.0						
3.0	0.026	0.193	64.3						
4.0	0.0071	0.212	53.0						
5.0	0.0032	0.216	43.2						
7.0	0.0029	0.216	30.9						
10	0.0021	0.217	21.7						
12	0.0016	0.217	18.1						
17.5	0.0006	0.218	12.5						
20	0.0005	0.218	10.9						

COMPOUND: Chloroethane

STRUCTURE:



FORMULA: C_2H_5Cl **MOL. WT.** 64.52

FREUNDLICH PARAMETERS	pH		
	5.3		
K	0.59		
1/n	0.95		
Corr. Coef. r	1.0		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	0.59		
0.1	0.07		
0.01	0.007		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_1, mg/l

C_0, mg/l	0.1	0.01	0.001
1.0	14,000	> 100,000	> 100,000
0.1		12,000	> 100,000
0.01			11,000

GRANULAR CARBON COLUMN

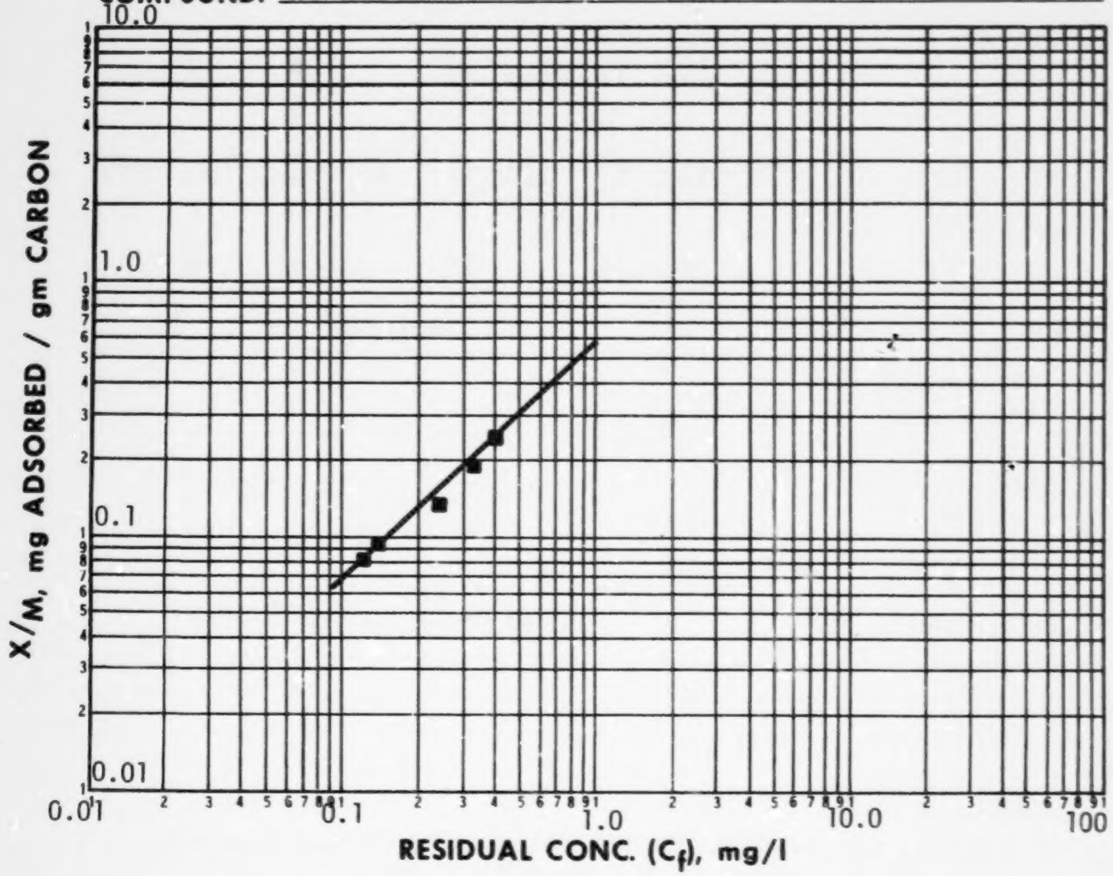
C_0, mg/l	
1.0	1700
0.1	1400
0.01	1400

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G. C. Purge and Trap

REMARKS:

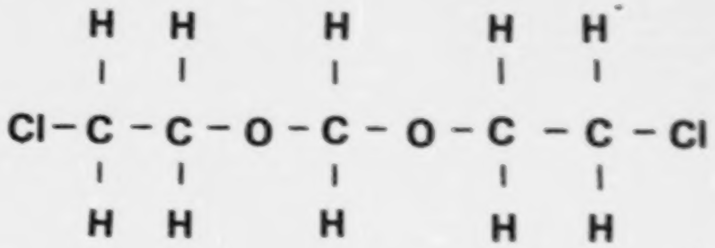
COMPOUND: Chloroethane



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	1.06								
2692	0.400	0.660	0.25						
3846	0.311	0.749	0.195						
5769	0.232	0.828	0.144						
9615	0.141	0.919	0.0956						
11,538	0.129	0.931	0.0807						

COMPOUND: Bis(2-chloroethoxy)methane

STRUCTURE:



$$\mathrm{Cl-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-O-\underset{H}{\overset{H}{C}}-O-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-Cl}$$

FORMULA: $C_5H_{10}O_2Cl_2$ **MOL. WT.** 173.1

FREUNDLICH PARAMETERS	pH		
	5.8		
K	11		
1/n	0.65		
Corr. Coef. r	0.91		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10.0	50		
1.0	11		
0.1	2.6		
0.01	0.6		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	350	1,700	7,800
0.1		160	770
0.01			70

GRANULAR CARBON COLUMN

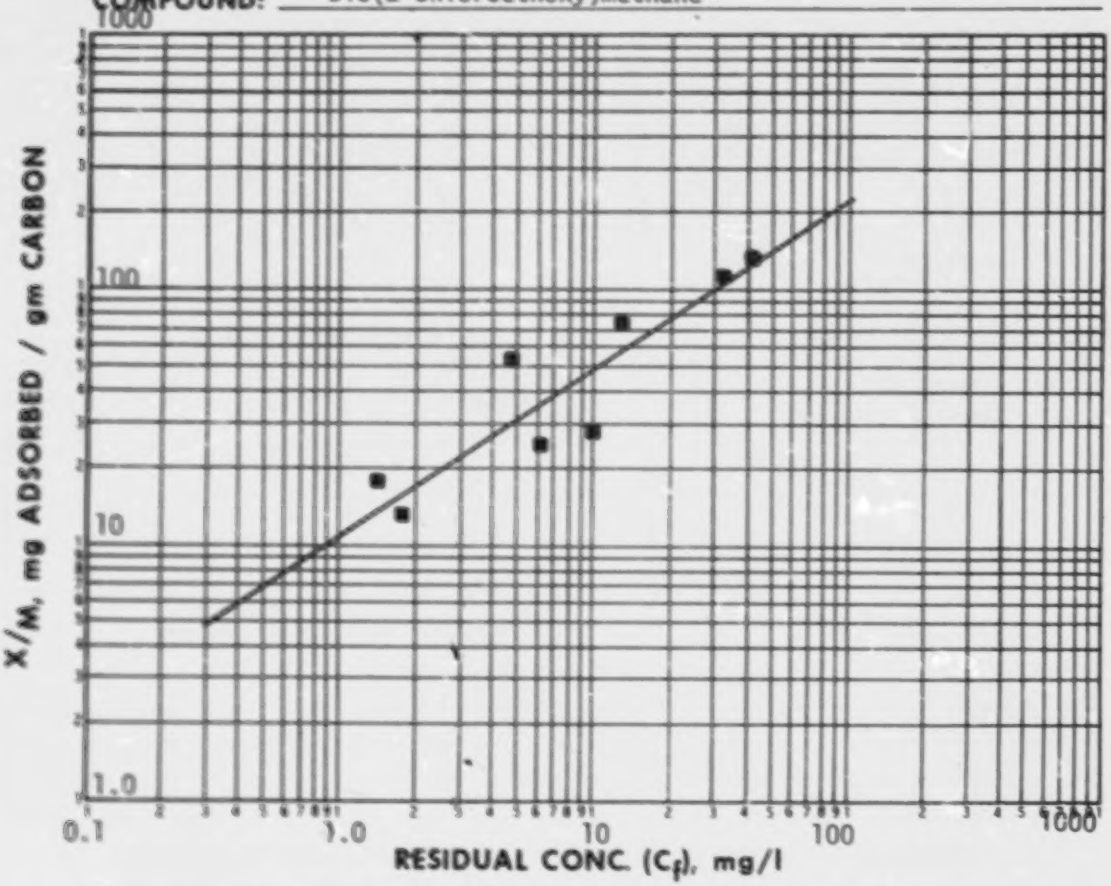
C_o, mg/l	
1.0	88
0.1	38
0.01	17

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Total Carbon

REMARKS:

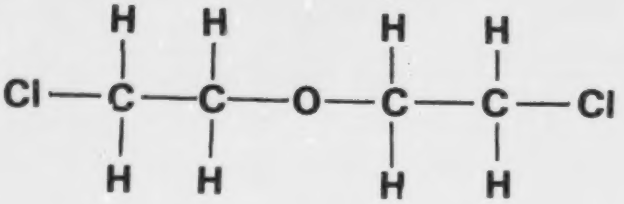
COMPOUND: Bis(2-chloroethoxy)methane



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	54.37								
96	41.11	13.26	138.4						
191	32.11	22.26	116.6						
573	12.85	41.52	72.52						
951	4.80	49.57	52.15						
1530	10.01	44.36	29.06						
1916	6.07	48.30	25.21						
2870	1.49	52.88	18.40						
3830	1.80	52.57	13.72						

COMPOUND: Bis(2-chloroethyl)ether

STRUCTURE:



$$\mathrm{Cl-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-O-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-Cl}$$

FORMULA: $C_4H_8OCl_2$ **MOL. WT.** 143.02

FREUNDLICH PARAMETERS	pH		
K	0.086		
1/n	1.84		
Corr. Coef. r	0.89		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10.0	6.0		
1.0	0.086		
0.1	0.001		
0.01	0.00002		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	>100,000	>100,000	>100,000
0.1		>100,000	>100,000
0.01			>100,000

GRANULAR CARBON COLUMN

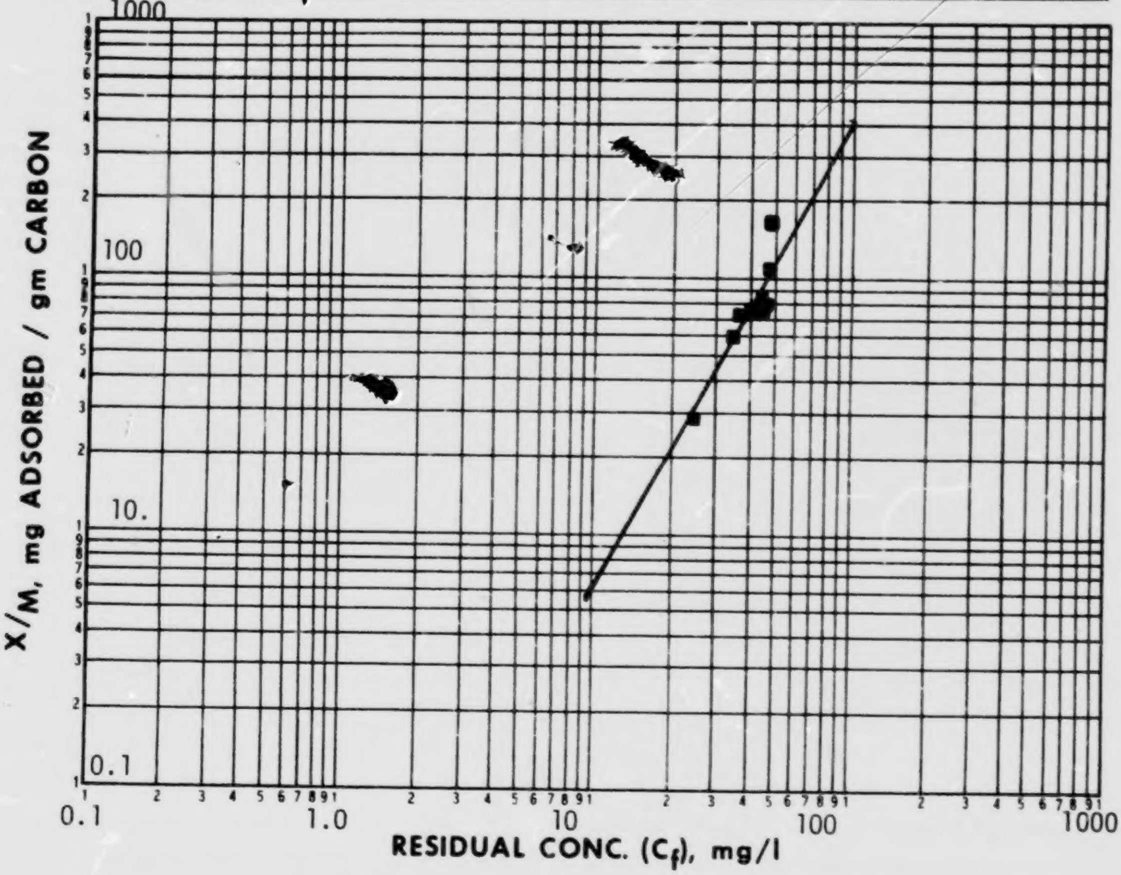
C_o, mg/l	
1.0	11,600
0.1	100,000
0.01	>100,000

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Total Carbon

REMARKS:

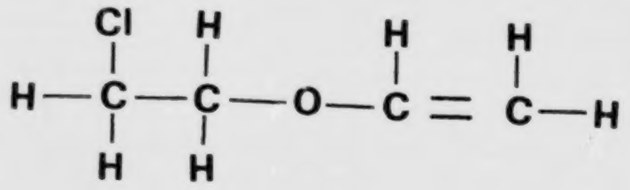
COMPOUND: Bis(2-chloroethyl)ether



	● pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	50.26								
9.12	48.68	1.58	173						
22.79	47.73	2.53	111						
45.58	46.62	3.64	79.9						
68.37	45.36	4.90	71.7						
91.16	42.67	7.59	83.3						
113.95	41.56	8.70	76.4						
137.11	39.67	10.59	77.2						
182.32	37.29	12.97	71.1						
274.22	33.97	16.29	59.4						
914.08	23.54	26.72	29.2						

COMPOUND: 2-Chloroethyl vinyl ether

STRUCTURE:



$H-\underset{H}{\overset{Cl}{C}}-\underset{H}{\overset{H}{C}}-O-\overset{H}{C}=\overset{H}{C}-H$

FORMULA: C_4H_7OCl **MOL. WT.** 106.55

FREUNDLICH PARAMETERS	pH		
	5.4		
K	3.9		
1/n	0.80		
Corr. Coef. r	0.94		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10.0	25		
1.0	3.9		
0.1	0.6		
0.01	0.1		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	1500	10,000	64,000
0.1		920	6,400
0.01			580

GRANULAR CARBON COLUMN

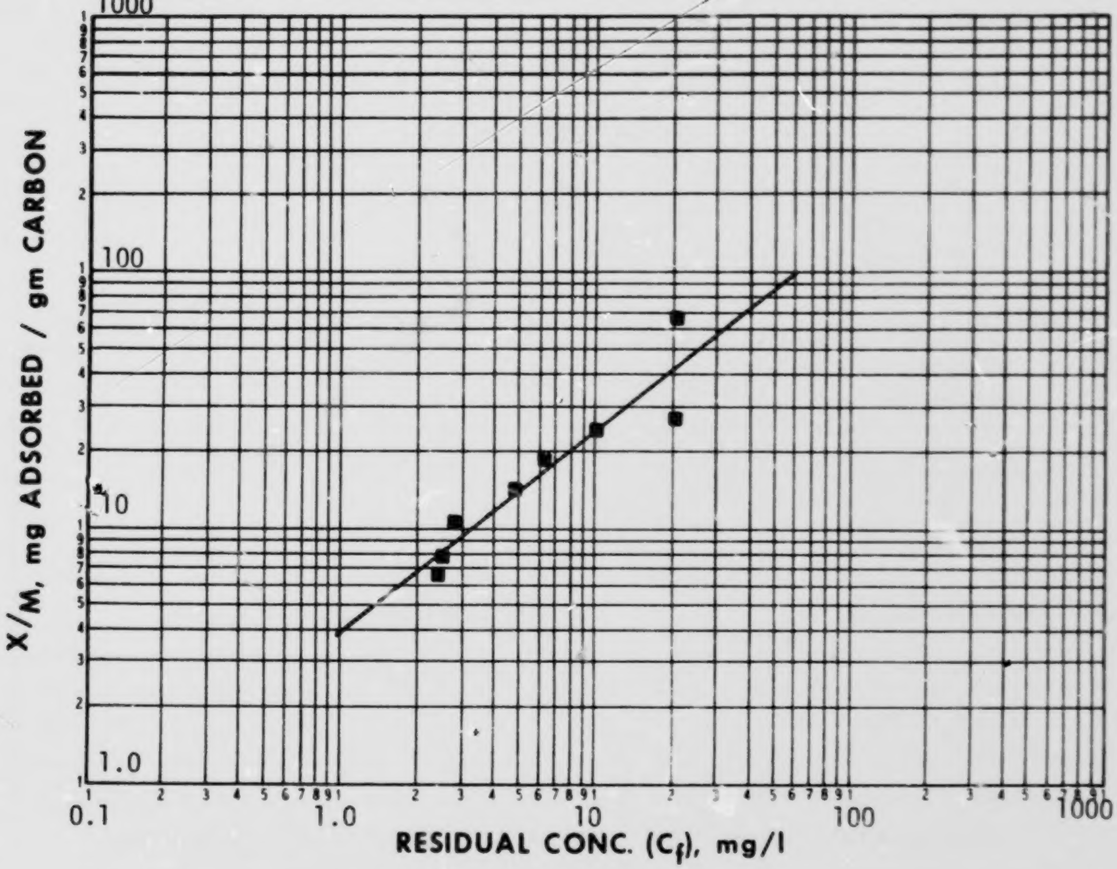
C_o, mg/l	
1.0	260
0.1	170
0.01	100

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Total Carbon

REMARKS:

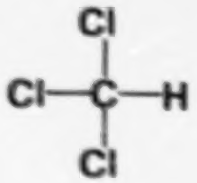
COMPOUND: 2-Chloroethyl vinyl ether



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	33.04								
191	20.35	12.69	66.50						
477	20.04	13.00	27.25						
951	10.09	22.95	24.14						
1430	6.24	26.80	18.72						
1916	4.92	28.12	14.68						
2870	2.78	30.26	10.53						
3830	2.48	30.56	7.98						
4960	2.28	30.76	6.20						

COMPOUND: Chloroform

STRUCTURE:



$CHCl_3$

FORMULA: $CHCl_3$ **MOL. WT.** 119.38

FREUNDLICH PARAMETERS	pH		
	5.3		
K	2.6		
1/n	0.73		
Corr. Coef. r	0.98		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	2.6		
0.1	0.48		
0.01	0.09		
0.001	0.02		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_0, mg/l	0.1	0.01	0.001
1.0	1900	11,000	50,000
0.1		1,000	6,000
0.01			540

GRANULAR CARBON COLUMN

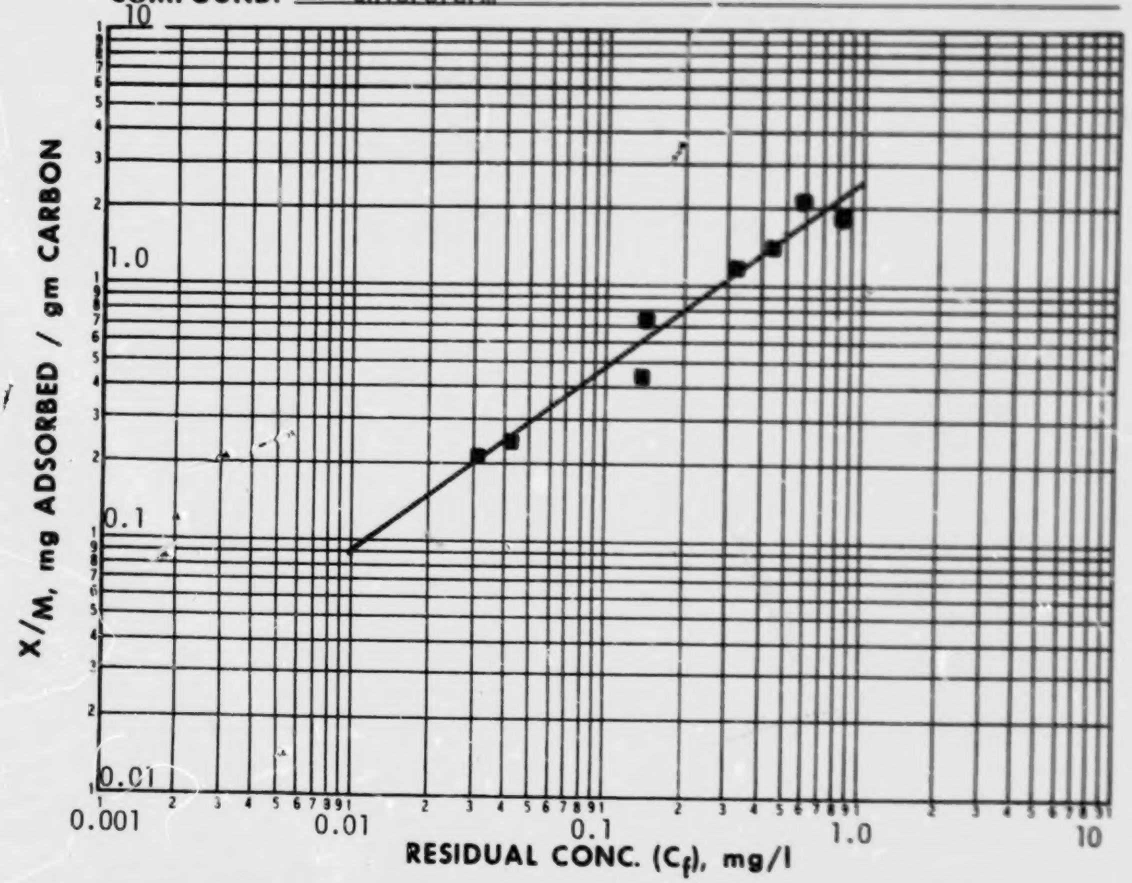
C_0, mg/l	
1.0	4,300
0.1	210
0.01	111

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G. C. Purge and Trap

REMARKS:

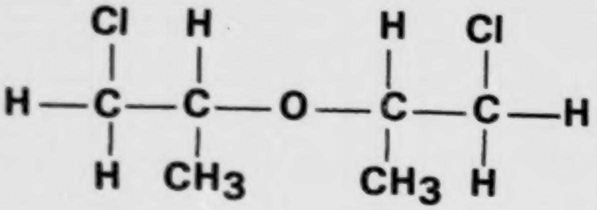
COMPOUND: Chloroform



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	1.000								
96	0.820	0.180	1.87						
192	0.596	0.404	2.10						
385	0.428	0.573	1.49						
577	0.314	0.686	1.19						
1154	0.149	0.851	0.738						
1923	0.145	0.855	0.445						
3846	0.041	0.959	0.249						
4615	0.030	0.970	0.210						

COMPOUND: Bis(2-chloroisopropyl)ether

STRUCTURE:



$$\begin{array}{ccccccccccc} & & Cl & & H & & & & H & & Cl & & \\ & & | & & | & & & & | & & | & & \\ H & - & C & - & C & - & O & - & C & - & C & - & H \\ & & | & & | & & & & | & & | & & \\ & & H & & CH_3 & & & & CH_3 & & H & & \end{array}$$

FORMULA: $C_6H_{12}OCl_2$ **MOL. WT.** 171.07

FREUNDLICH PARAMETERS	pH		
	5.4		
K	24		
1/n	0.57		
Corr. Coef. r	0.91		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10.0	88.0		
1.0	24		
0.1	6.3		
0.01	1.7		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON
C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	140	580	2,200
0.1		55	220
0.01			20

GRANULAR CARBON COLUMN

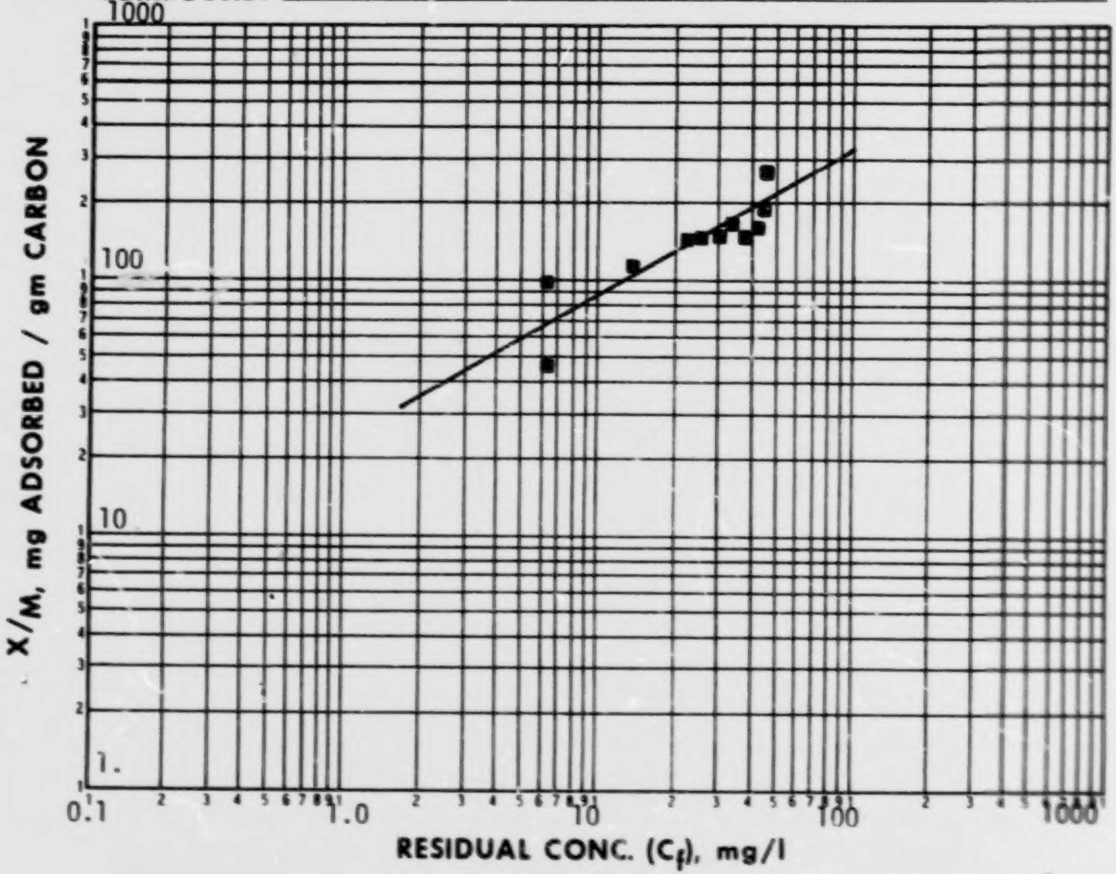
C_o, mg/l	
1.0	43
0.1	16
0.01	5.9

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Total Carbon

REMARKS:

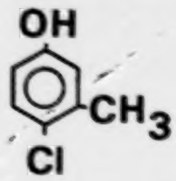
COMPOUND: Bis(2-chloroisopropyl)ether



	● pH= 5.4			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	C_o-C_f=X	X/M	C_f	C_o-C_f=X	X/M
0	48.43								
9.1	45.94	2.49	273						
22.8	44.00	4.43	194.4						
45.6	40.81	7.62	167.2						
68.4	37.62	10.81	158.1						
91.2	32.64	15.79	173.2						
114	30.14	18.29	160.5						
137	26.68	21.75	158.6						
182	21.55	26.88	147.4						
274	14.49	33.94	123.8						
457	6.45	41.98	91.85						
914	6.17	42.26	46.23						

COMPOUND: Parachlorometa cresol

STRUCTURE:



FORMULA: C_7H_7C10 **MOL. WT.** 142.59

FREUNDLICH PARAMETERS	pH		
	3.0	5.5	9.0
K	122	124	99
1/n	0.29	0.16	0.42
Corr. Coef. r	0.90	0.87	0.97
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	122	124	99
0.1	63	85	38
0.01	32	58	14
0.001	17	40	5.5

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	11	17	25
0.1		1.6	2.5
0.01			0.2

GRANULAR CARBON COLUMN

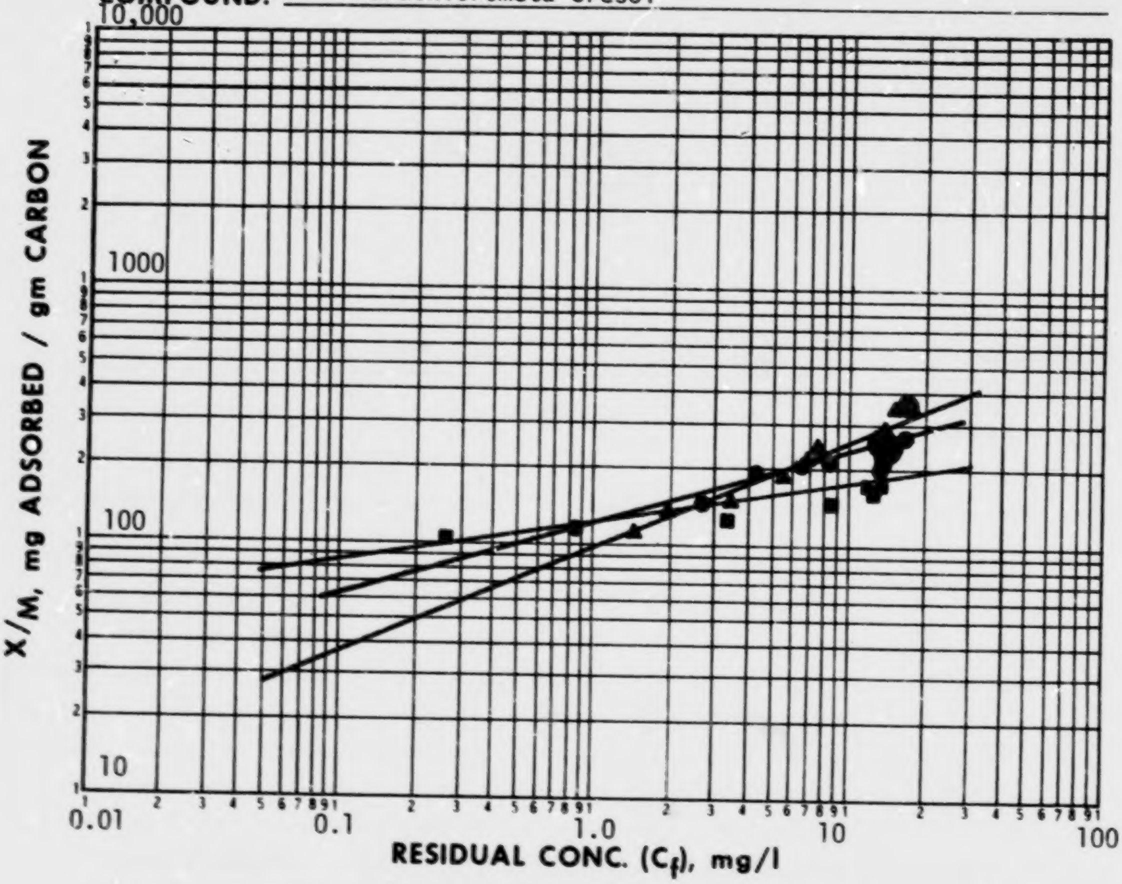
C_o, mg/l	
1.0	8.1
0.1	1.2
0.01	0.2

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 225.9 nm.

REMARKS:

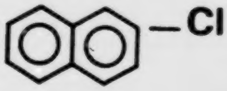
COMPOUND: Parachlorometa cresol



	● pH= 3.0			■ pH= 5.5			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	18.92			16.34			19.90		
2.5	17.96	0.96	384						
5.0	17.52	1.40	280	15.13	1.21	242	18.12	1.78	356
7.5	16.96	1.96	261						
10	16.25	2.67	267	14.19	2.15	215	16.35	3.55	355
20	13.64	5.28	264	12.88	3.46	173	14.03	5.87	294
25	13.92	5.00	200	11.92	4.42	177	13.94	5.96	238
50	8.50	10.42	208	8.55	7.79	156	7.40	12.50	250
60	6.73	12.19	203				6.95	12.95	216
75	4.26	14.66	196				5.43	14.47	193
100	2.82	16.10	161	3.22	13.12	131	3.38	16.52	165
150	0.86	18.06	120	0.27	16.07	107	1.52	18.38	122
200							1.10	18.80	94

COMPOUND: 2-Chloronaphthalene

STRUCTURE:



FORMULA: $C_{10}H_7Cl$ **MOL. WT.** 162.62

FREUNDLICH PARAMETERS	pH		
	5.5		
K	280		
1/n	0.46		
Corr. Coef. r	0.96		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	280		
0.1	96		
0.01	33		
0.001	11		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	9.3	29	86
0.1		2.7	8.5
0.01			0.8

GRANULAR CARBON COLUMN

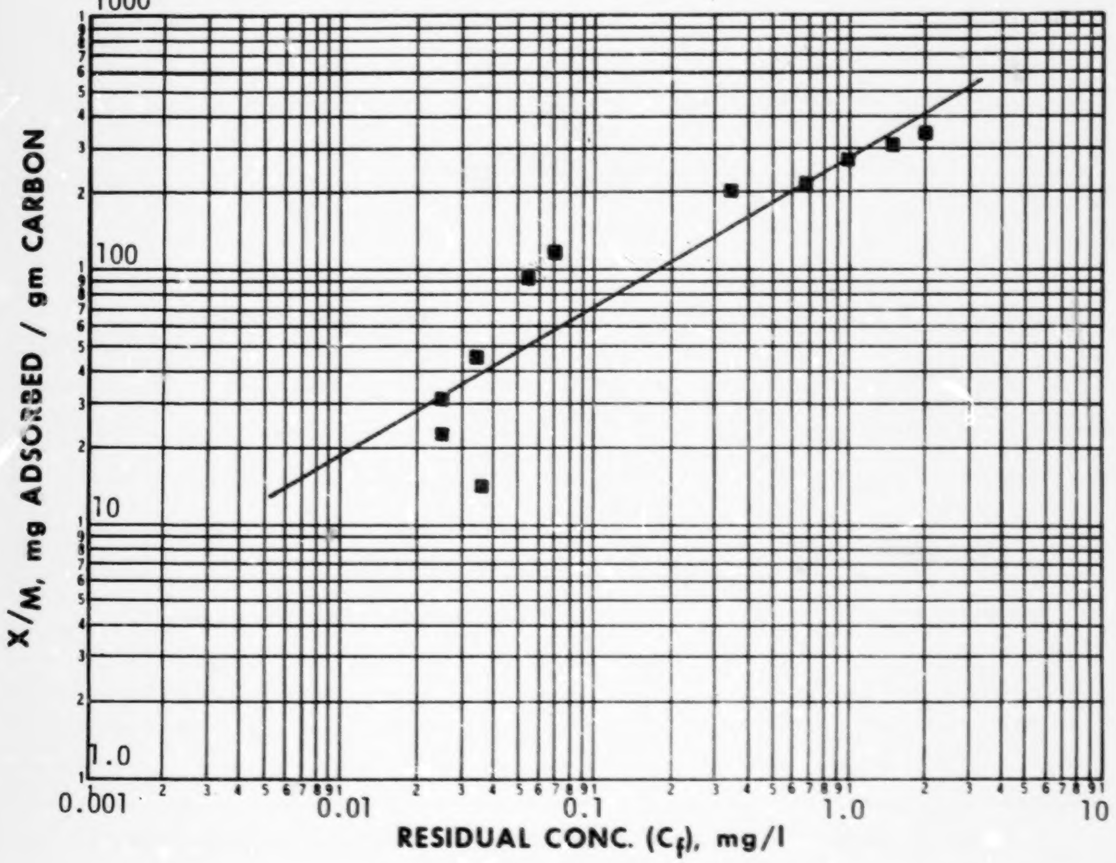
C_o, mg/l	
1.0	3.6
0.1	1.0
0.01	0.3

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 224.5 nm.

REMARKS:

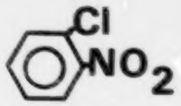
COMPOUND: 2-Chloronaphthalene



	■ pH= 5.5			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	C_o-C_f=X	X/M	C_f	C_o-C_f=X	X/M
0	2.36								
1.0	2.01	0.35	350						
2.5	1.59	0.77	308						
5.0	0.98	1.38	276						
7.5	0.68	1.68	224						
10	0.34	2.02	202						
20	0.07	2.29	114						
25	0.05	2.31	92						
50	0.03	2.33	47						
75	0.02	2.34	31						

COMPOUND: 1-Chloro-2-nitrobenzene

STRUCTURE:



FORMULA: $C_6H_4ClNO_2$ **MOL. WT.** 157.6

FREUNDLICH PARAMETERS	pH		
	All data pooled		
K	130		
1/n	0.46		
Corr. Coef. r	0.97		
INITIAL CONC mg/l	ADSORPTION CAPACITY, mg/gm		
10	370		
1.0	130		
0.1	46		
0.01	16		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	20	64	180
0.1		5.8	18
0.01			1.7

GRANULAR CARBON COLUMN

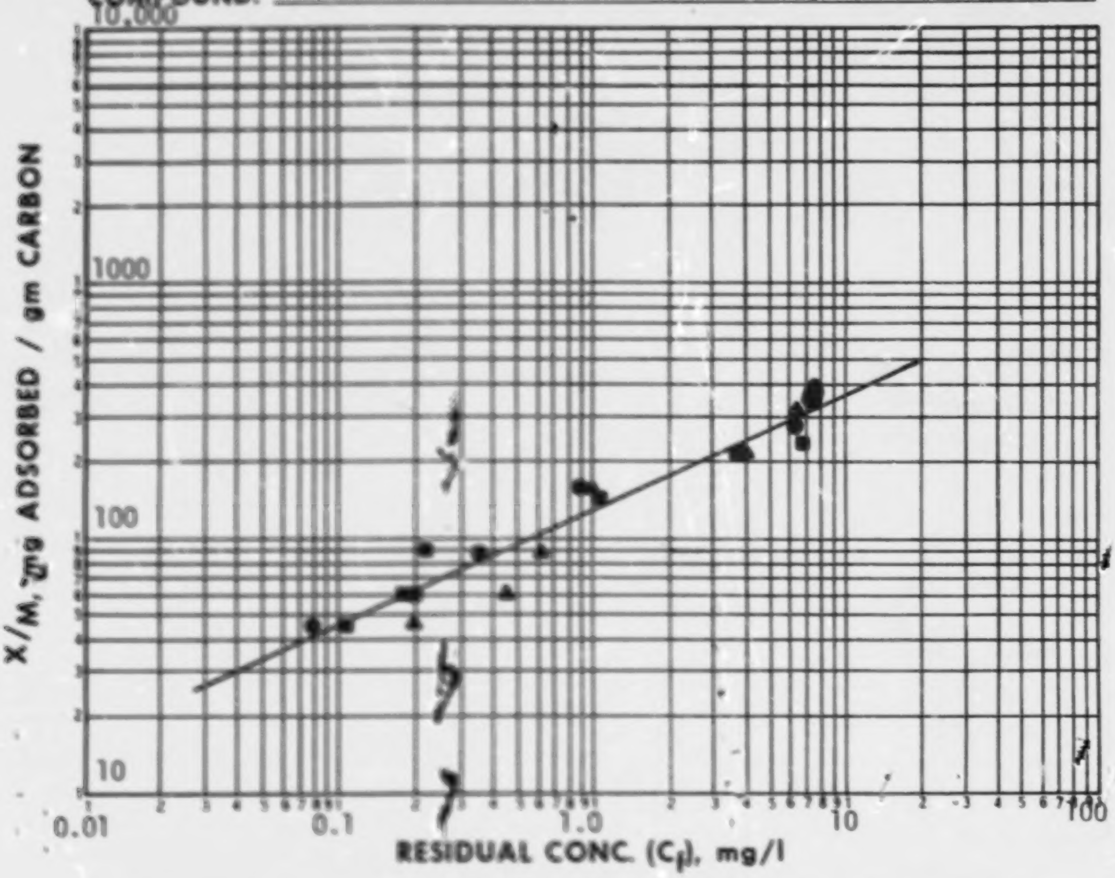
C_o, mg/l	
1.0	7.7
0.1	2.2
0.01	0.6

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 260 nm

REMARKS:

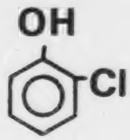
COMPOUND: 1-Chloro-2-nitrobenzene



	● pH= 3.0			■ pH=7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	9.26			9.20			9.43		
5	7.43	1.83	366	7.36	1.84	368	7.50	1.93	386
10	6.39	2.87	287	6.86	2.34	234	6.30	3.13	313
25	3.81	5.45	218	3.86	5.34	214	4.02	5.41	216
50	0:90	8.36	167	1.13	8.07	161	1.02	8.41	168
100	0.37	8.89	89	0.22	8.98	90	0.61	8.82	88
150	0.20	9.06	60	0.18	9.02	60	0.46	8.97	60
200	0.08	9.18	46	0.11	9.09	45	0.20	9.23	46

COMPOUND: 2-Chlorophenol

STRUCTURE:



FORMULA: C_6H_5OCl **MOL. WT.** 125.56

FREUNDLICH PARAMETERS	pH		
	All Data Pooled		
K	51.0		
1/n	0.41		
Corr. Coef. r	0.97		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	51		
0.1	20		
0.01	7.9		
0.001	3.1		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	45	130	330
0.1		12	33
0.01			3.0

GRANULAR CARBON COLUMN

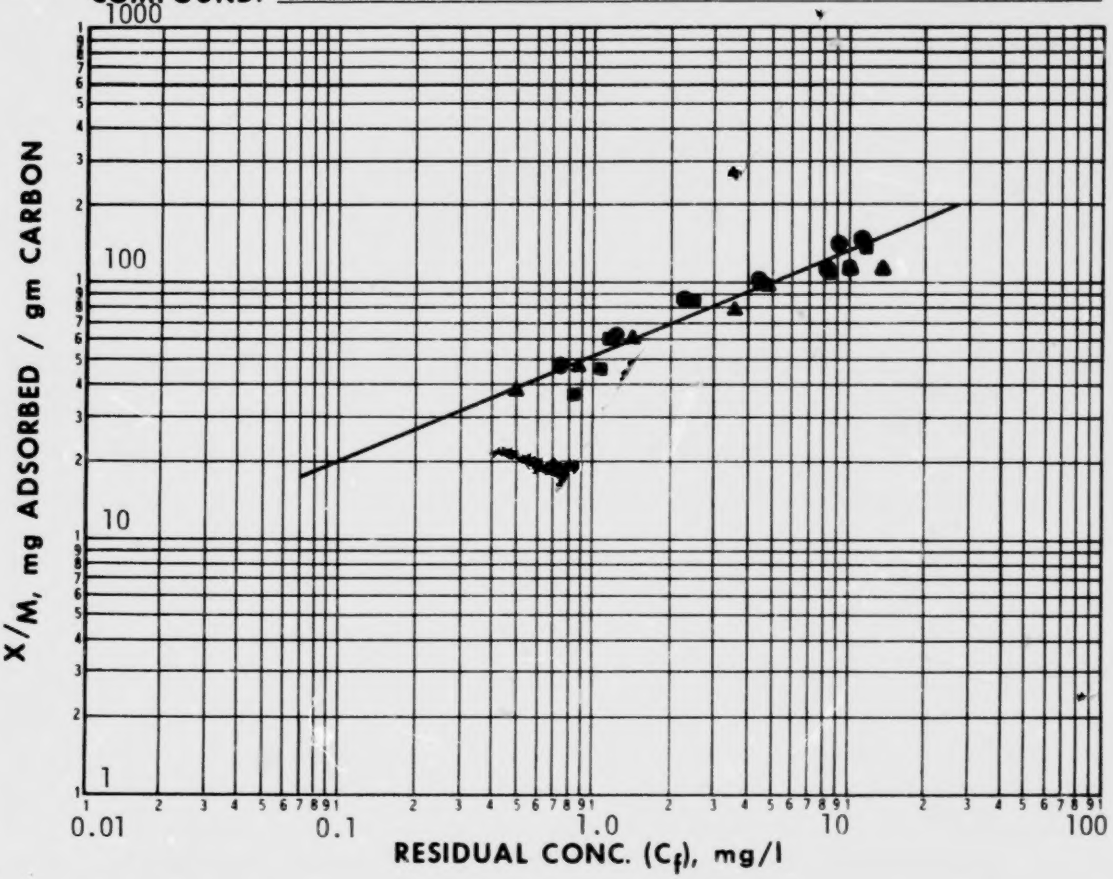
C_o, mg/l	
1.0	20
0.1	5.0
0.01	1.3

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 273.5 nm.

REMARKS:

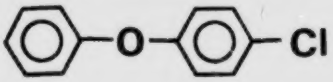
COMPOUND: 2-Chlorophenol



	● pH= 3.0			■ pH= 5.8			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	20.00			19.32			19.61		
50	12.16	7.84	157	12.10	7.22	144	13.51	6.10	122
75	9.14	10.86	145	10.22	9.10	121	10.40	9.21	123
100	8.12	11.88	119	8.28	11.04	110	8.38	11.23	112
150	4.50	15.50	103	4.42	14.90	99.3	4.88	14.73	98.2
200	2.34	17.76	88.3	2.54	16.78	83.9	3.66	15.95	79.8
300	1.30	18.70	62.3	1.24	18.08	60.3	1.48	18.13	60.4
400	0.76	19.24	48.1	1.10	18.22	45.6	0.89	18.72	46.8
500				0.82	18.50	37.0	0.50	19.11	38.2

COMPOUND: 4-Chlorophenyl phenyl ether

STRUCTURE:



FORMULA: $C_{12}H_9OCl$ **MOL. WT.** 204.66

FREUNDLICH PARAMETERS	pH		
	5.3		
K	111		
1/n	0.26		
Corr. Coef. r	0.96		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	111		
0.1	61		
0.01	33		
0.001	18		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON
C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	15	30	55
0.1		2.7	5.4
0.01			0.5

GRANULAR CARBON COLUMN

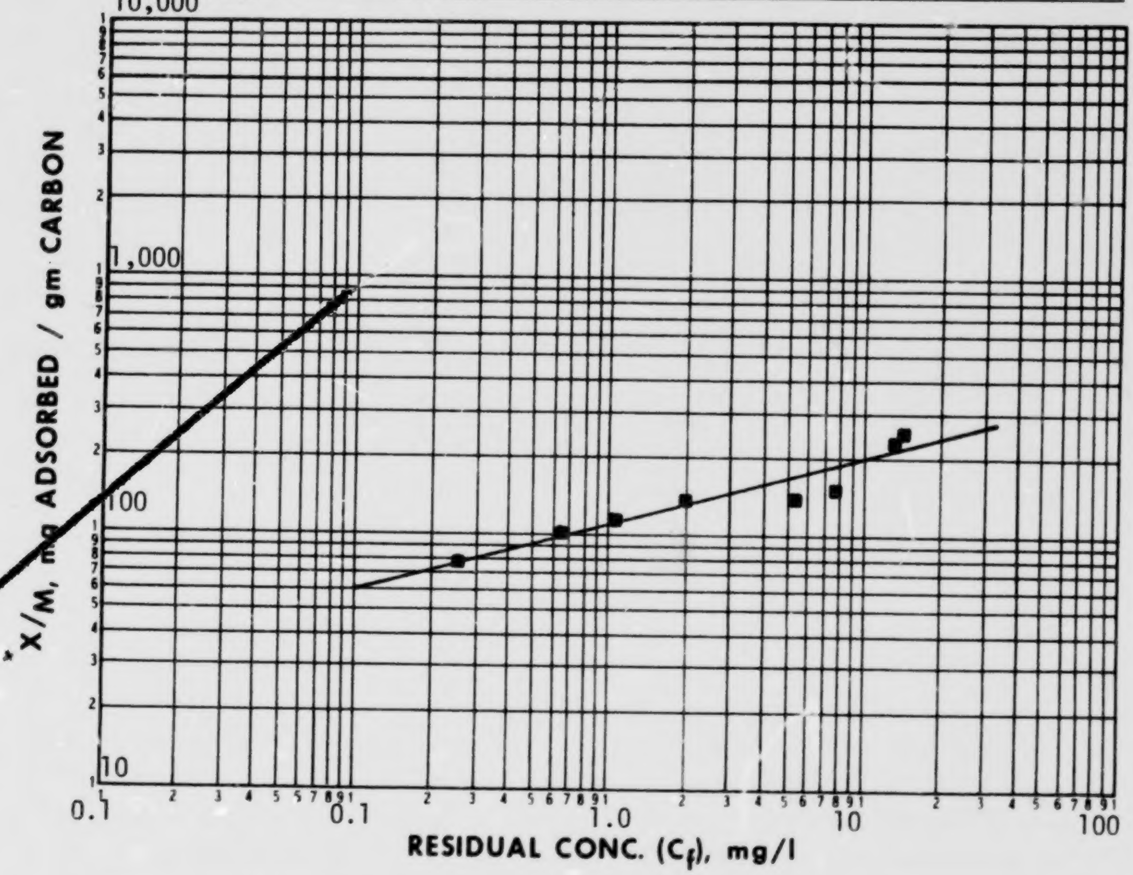
C_o, mg/l	
1.0	9.0
0.1	1.6
0.01	0.3

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 225.6 nm.

REMARKS:

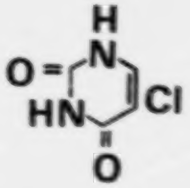
COMPOUND: 4-Chlorophenyl phenyl ether



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	15.94								
5	14.63	1.31	262						
10	13.60	2.34	234						
50	7.75	8.19	163.8						
75	5.36	10.58	141.1						
100	2.01	13.93	139.3						
125	1.09	14.85	118.8						
150	0.67	15.27	101.8						
200	0.26	15.68	78.4						

COMPOUND: 5-Chlorouracil

STRUCTURE:



FORMULA: $C_4H_3N_2O_2Cl$ **MOL. WT.** 146.54

FREUNDLICH PARAMETERS	pH		
	pH 3 and 7 pooled	pH 9	
K	25	7.3	
1/n	0.58	0.90	
Corr. Coef. r	0.98	0.76	
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	96	58	
1.0	25	7.3	
0.1	6.6	0.91	
0.01	1.7	0.11	

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	140	570	2,200
0.1		52	220
0.01			20

GRANULAR CARBON COLUMN

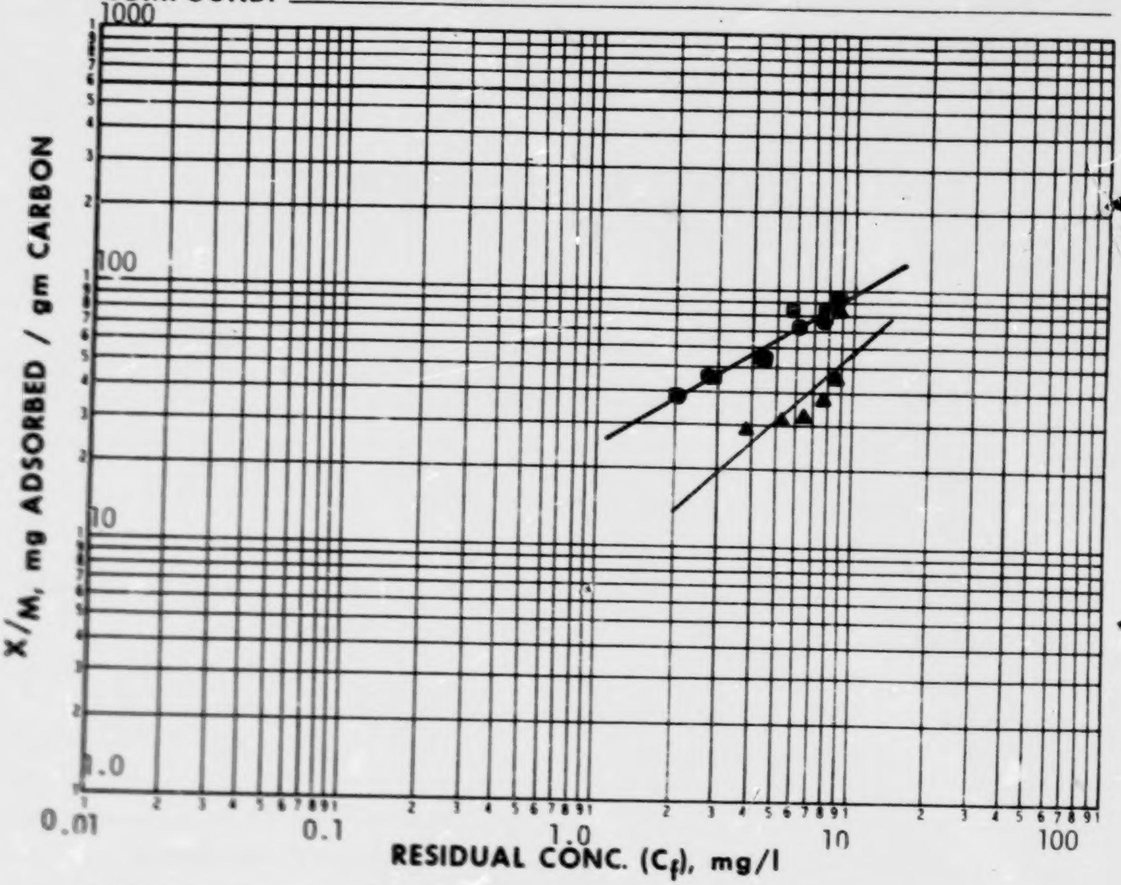
C_o, mg/l	
1.0	40
0.1	15
0.01	5.8

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 273 nm

REMARKS:

COMPOUND: 5-Chlorouracil



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	9.84			9.89			9.80		
10	8.92	0.92	92	8.96	0.93	93	8.99	0.81	81
25	7.89	1.95	78	7.83	2.06	82	8.65	1.15	46
50	6.24	3.60	72	5.81	4.08	82	7.89	1.91	38
100	4.38	5.46	55	4.45	5.44	54	6.58	3.22	32
150	2.82	7.02	47	2.98	6.91	46	5.22	4.58	31
200	2.07	7.77	39	2.01	7.88	39	3.93	5.87	29

COMPOUND: Choline chloride

STRUCTURE:

$$[(CH_3)_3N^+ \cdot CH_2CH_2OH]Cl^-$$

FORMULA: $C_5H_{14}ClNO$ **MOL. WT.** 139.63

FREUNDLICH PARAMETERS	pH		
K			
1/n			
Corr. Coef. r			
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l			

GRANULAR CARBON COLUMN

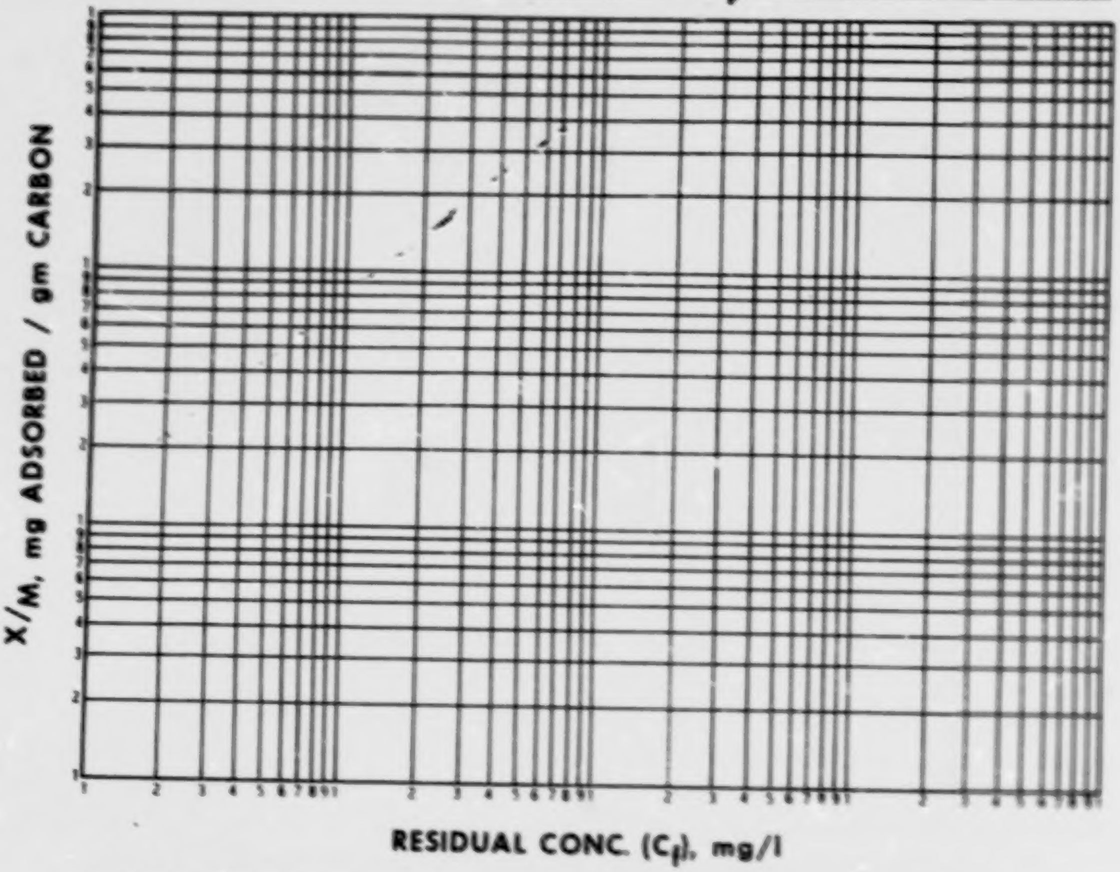
C_o, mg/l	

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Total Organic Carbon

REMARKS: Not adsorbed

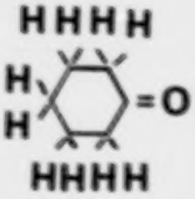
COMPOUND: Choline chloride



	pH= 3.0			pH= 7.0			pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	13.2			14.0			14.0		
5	13.6			13.6			14.6		
10	12.8			15.0			13.4		
25	13.8			13.2			13.6		
50	13.2			12.4			14.6		
100	13.6			13.2			14.0		
150	13.6			14.2			13.0		
200	12.6			12.6			13.2		

COMPOUND: Cyclohexanone

STRUCTURE:



FORMULA: $C_6H_{10}O$ **MOL. WT.** 98.14

FREUNDLICH PARAMETERS	pH		
	7.3		
K	6.2		
1/n	0.75		
Corr. Coef. r	0.84		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	36		
1.0	6.2		
0.1	1.1		
0.01	0.19		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	820	5,100	29,000
0.1		470	2,900
0.01			260

GRANULAR CARBON COLUMN

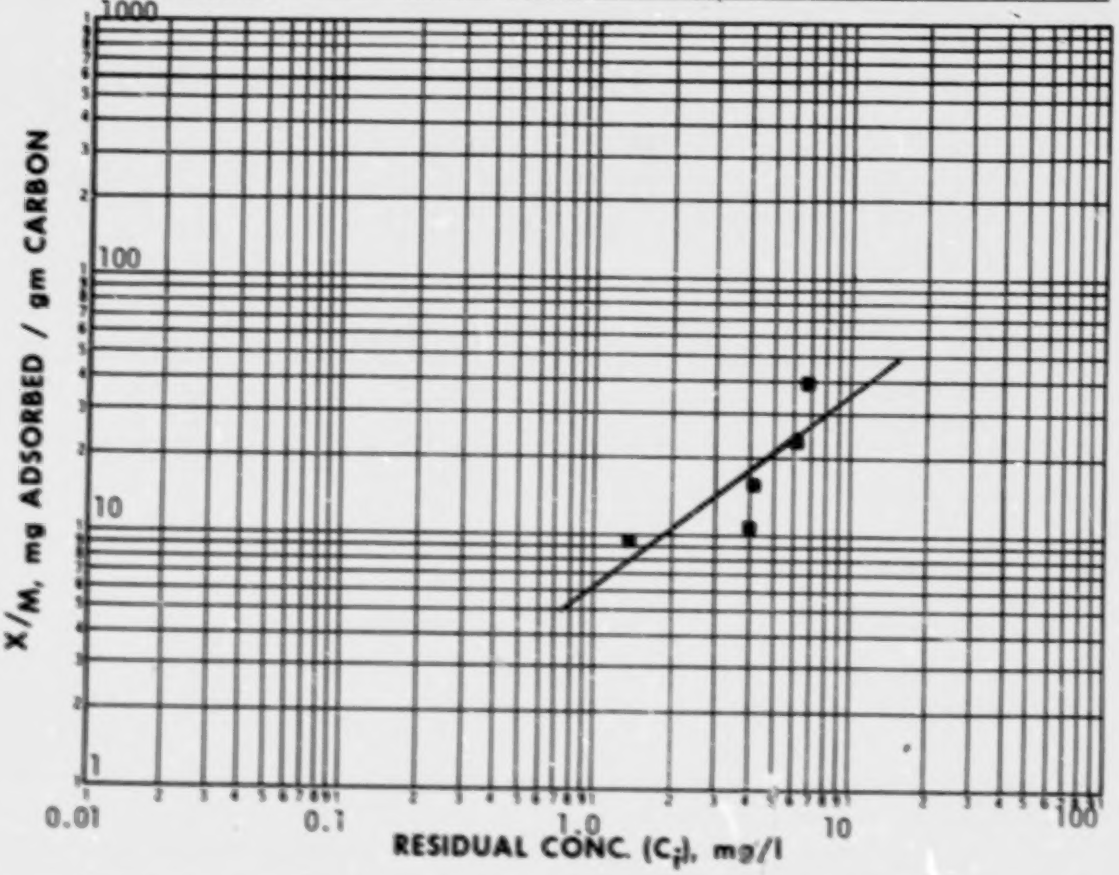
C_o, mg/l	
1.0	160
0.1	91
0.01	52

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Total Organic Carbon

REMARKS:

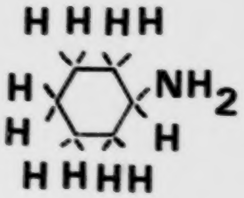
COMPOUND: Cyclohexanone



	● pH= 7.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	10.76								
100	6.81	3.95	39.5						
200	6.13	4.63	23.2						
400	4.09	6.67	16.7						
600	3.95	6.81	11.4						
1000	1.36	9.40	9.4						

COMPOUND: Cyclohexylamine

STRUCTURE:



FORMULA: $C_6H_{13}N$ **MOL. WT.** 99.2

FREUNDLICH PARAMETERS	**pH**		
K			
1/n			
Corr. Coef. r			
INITIAL CONC. mg/l	**ADSORPTION CAPACITY, mg/gm**		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON
C_f, mg/l

C_o, mg/l			

GRANULAR CARBON COLUMN

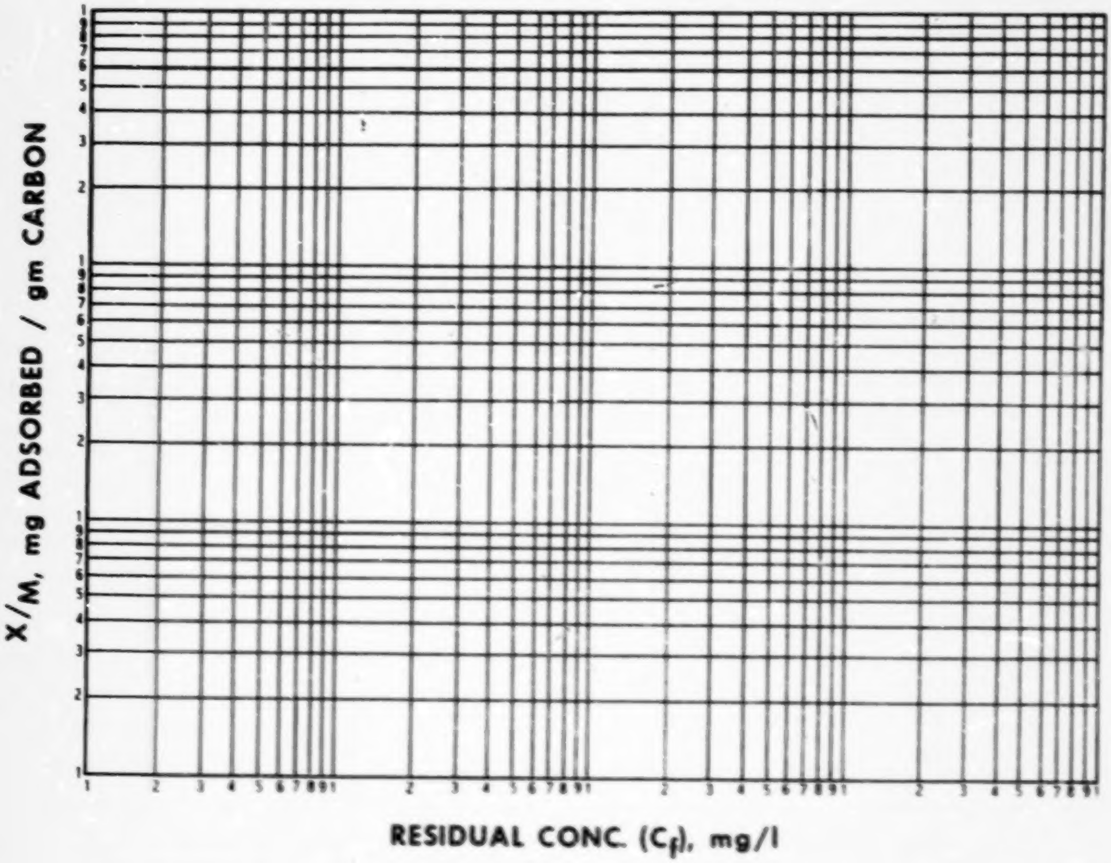
C_o, mg/l	

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Total Organic Carbon

REMARKS: Not adsorbed

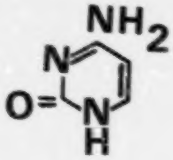
COMPOUND: Cyclohexylamine



	pH= 3.0			pH= 7.0			pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	10.4			10.8			12.8		
5	10.4			10.2			11.6		
10	9.8			10.6			11.8		
25	9.4			10.4			10.6		
50	10.2			11.0			11.0		
100	9.8			10.4			10.4		
150	9.8			11.2			10.8		
200	10.6			10.0			10.0		

COMPOUND: Cytosine

STRUCTURE:



FORMULA: $C_4H_5N_3O$ **MOL. WT.** 111.10

FREUNDLICH PARAMETERS	pH		
	3.0	pH 7 and 9 pooled	
K	6.3×10^{-13}	1.1	
1/n	13.67	1.6	
Corr. Coef. r	0.90	0.98	
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	30	38	
1.0		1.1	
0.1		0.03	
0.01		0.0008	

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON
C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	> 30,000	> 100,000	> 100,000
0.1		> 100,000	> 100,000
0.01			> 100,000

GRANULAR CARBON COLUMN

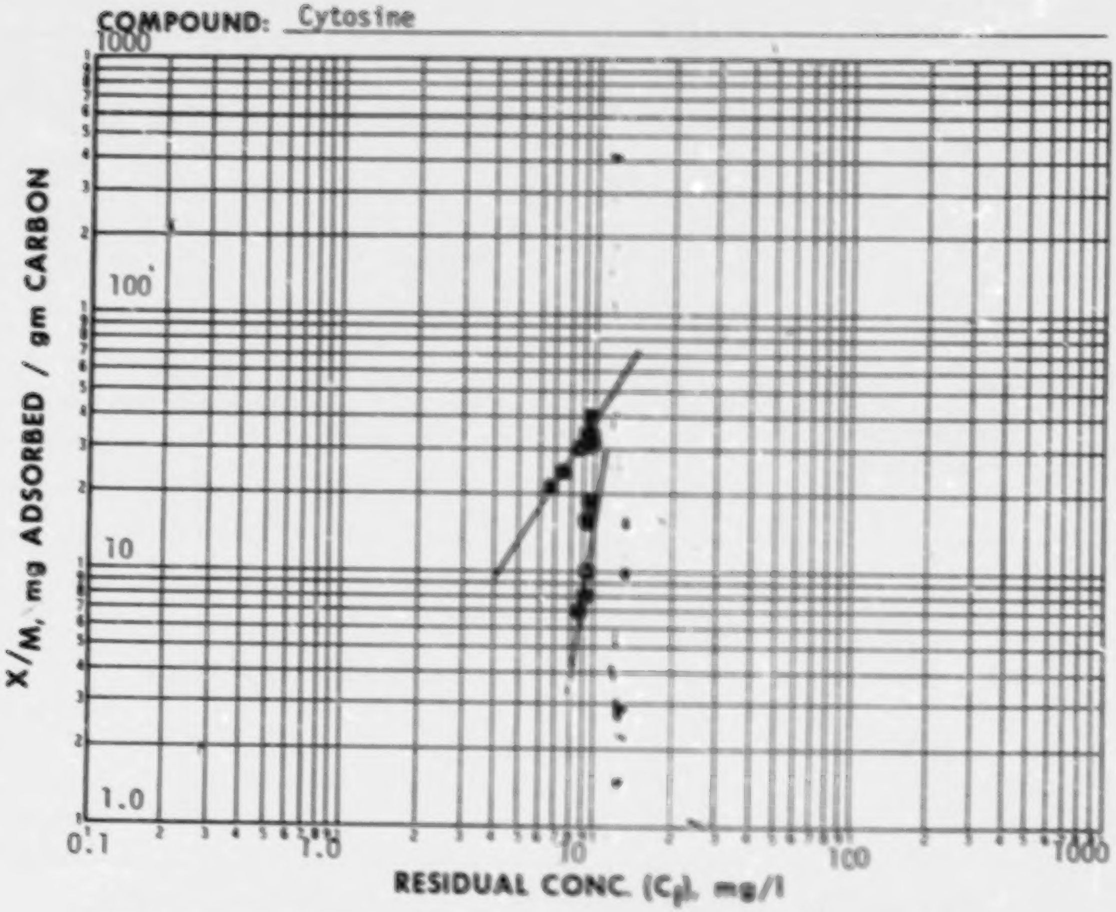
C_o, mg/l	
1.0	935
0.1	3,330
0.01	12,500

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 275 nm

REMARKS:

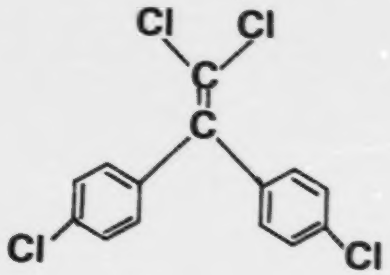
COMPOUND: Cytosine



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	9.96			10.00			9.98		
5	9.80	0.16	32	9.80	0.20	40	9.80	0.18	36
10	9.77	0.19	19	9.64	0.36	36	9.63	0.35	35
25	9.53	0.43	17	9.15	0.85	34	9.20	0.78	31
50	9.48	0.48	10	8.48	1.52	30	8.49	1.49	30
100	9.18	0.78	8	7.53	2.47	25	7.54	2.44	24
150	8.87	1.09	7	6.30	3.20	21	6.81	3.17	21

COMPOUND: DDE

STRUCTURE:



FORMULA: $C_{14}H_8Cl_4$ **MOL. WT.** 318.03

FREUNDLICH PARAMETERS	pH		
	5.3		
K	232		
1/n	0.37		
Corr. Coef. r	0.82		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	232		
0.1	98		
0.01	42		
0.001	18		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	9.0	23	55
0.1		2.1	5.5
0.01			0.5

GRANULAR CARBON COLUMN

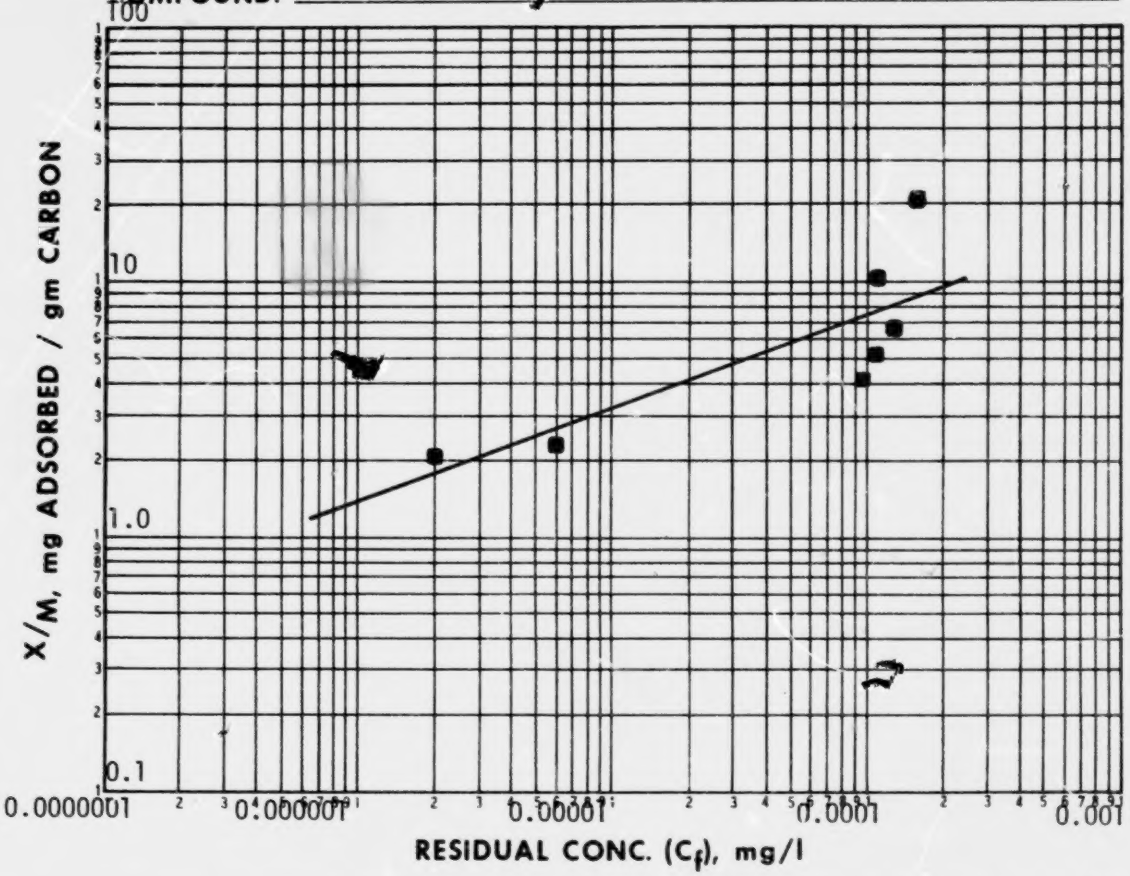
C_o, mg/l	
1.0	4.3
0.1	1.0
0.01	0.2

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent Extraction - G.C.

REMARKS:

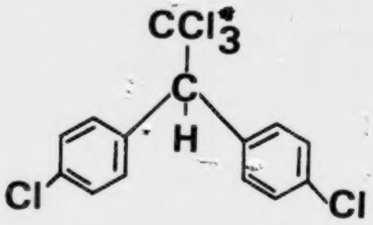
COMPOUND: DDE



	● pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f*	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	20.7								
1.0	0.169	0.02053	20.5						
2.0	0.114	0.0206	10.3						
3.0	0.129	0.02057	6.86						
4.0	0.112	0.02059	5.15						
5.0	0.098	0.02060	4.12						
9.0	0.006	0.02069	2.30						
10.0	0.002	0.02070	2.07						
*	X10^3								

COMPOUND: DDT

STRUCTURE:



FORMULA: $C_{14}H_9C_{15}$ **MOL. WT.** 354.50

FREUNDLICH PARAMETERS	pH		
	5.3		
K	322		
1/n	0.50		
Corr. Coef. r	0.89		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	322		
0.1	103		
0.01	33		
0.001	10		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	8.8	31	98
0.1		2.8	9.7
0.01			0.9

GRANULAR CARBON COLUMN

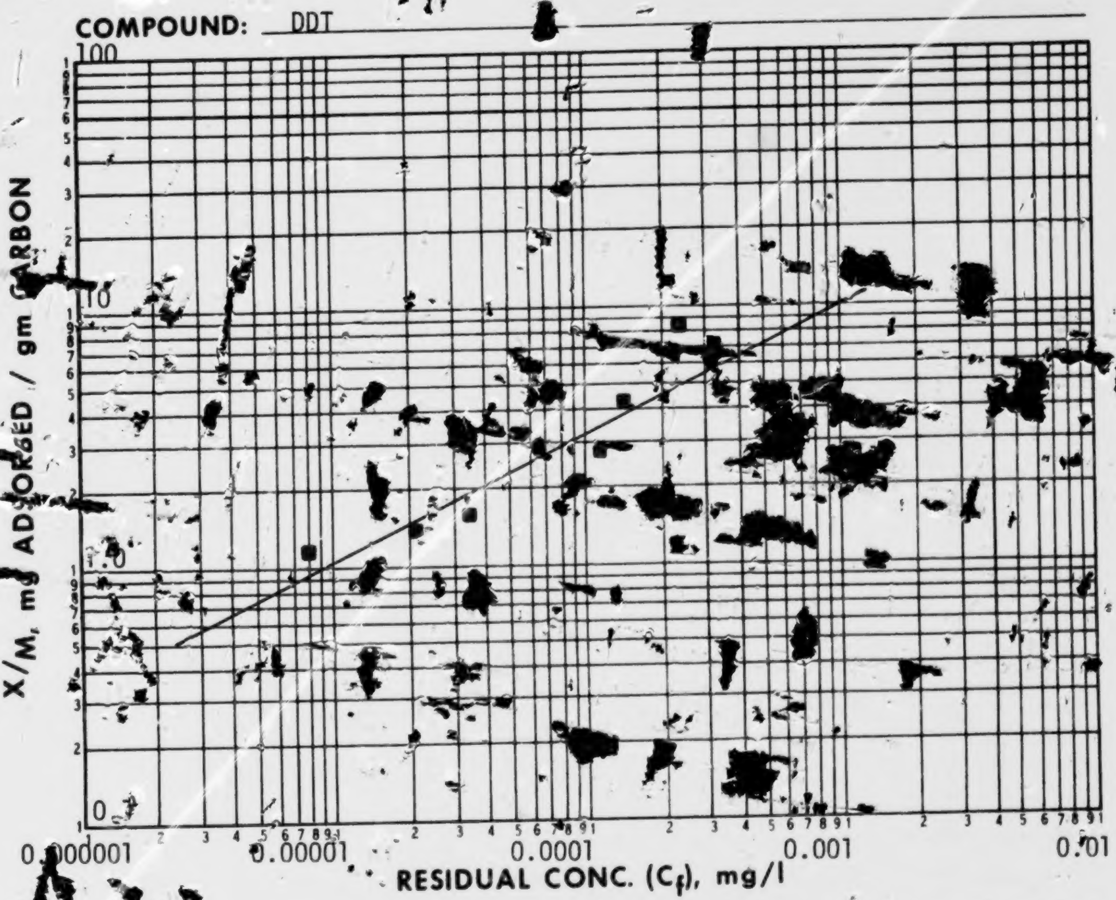
C_o, mg/l	
1.0	3.1
0.1	1.0
0.01	0.3

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent Extraction - G.C.

REMARKS:

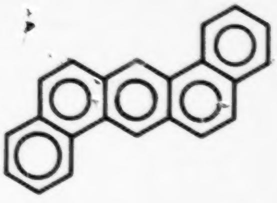
COMPOUND: DDT



	pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	[illegible]*	$C_o-C_f=X$*	X/M	C_f	$C_o-C_f=X$	X/M	[illegible]	$C_o-C_f=X$	X/M
0	8.64								
1.0	0.234	8.41	8.41						
2.0	0.147	8.49	4.25						
3.0	0.121	8.52	2.84						
4.0	0.091	8.55	2.14						
5.0	0.034	8.61	1.72						
6.0	0.021	8.62	1.44						
7.0	0.008	8.63	1.23						
* X 10^3									

COMPOUND: Dibenzo(a,h)anthracene

STRUCTURE:



FORMULA: $C_{22}H_{14}$ **MOL. WT.** 278.33

FREUNDLICH PARAMETERS	pH		
	7.1		
K	69.3		
1/n	0.75		
Corr. Coef. r	0.97		
INITIAL CONC. mg/l	**ADSORPTION CAPACITY, mg/gm**		
1.0	69		
0.1	12		
0.01	2.1		
0.001	0.39		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_o, mg/l	C_f, mg/l		
	0.1	0.01	0.001
1.0	73	450	2600
0.1		41	250
0.01			23

GRANULAR CARBON COLUMN

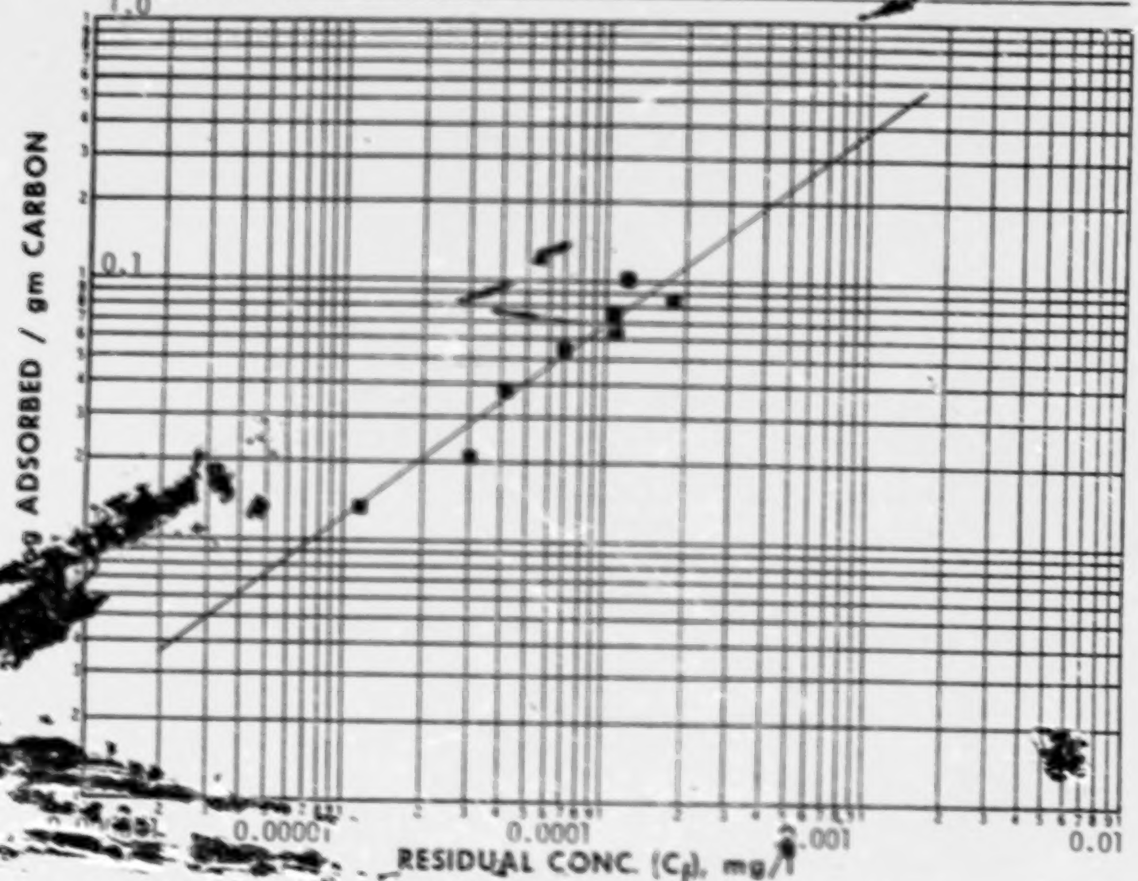
C_o, mg/l	
1.0	14
0.1	8.3
0.01	4.8

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Fluorescence: excitation 298 nm; 395 nm.

REMARKS: Modified protocol used for isotherm due to limited solubility.

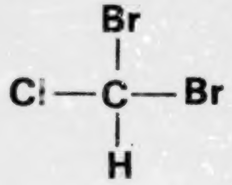
COMPOUND: Dibenzo(a,h)anthracene



CARBON DOSE mg/l	$C_o \times 10^3$	$C_f \times 10^3$	[illegible]	X/M
0.72	0.199	[illegible]	[illegible]	0.101
0.74	0.166	0.109	0.000057	0.077
2.34	0.133	0.041	0.000092	0.039
2.82	0.428	0.182	0.000240	0.087
[illegible]	0.29[illegible]	0.114	0.000184	0.064
3.18	0.246	0.070	0.000176	0.055
6.94	0.112	0.012	0.000100	0.014
7.46	0.185	[illegible]	0.000155	0.021

COMPOUND: Dibromochloromethane

STRUCTURE:



FORMULA: CHBrCl **MOL. WT.** 208.29

FREUNDLICH PARAMETERS	pH		
	5.3		
K	4.8		
1/n	0.34		
Corr. Coef. r	0.96		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	4.8		
0.1	2.2		
0.01	1.0		
0.001	0.46		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

	C_f, mg/l		
C_0, mg/l	0.1	0.01	0.001
1.0	[illegible]10	980	2,200
0.1		89	210
0.01			19

GRANULAR CARBON COLUMN

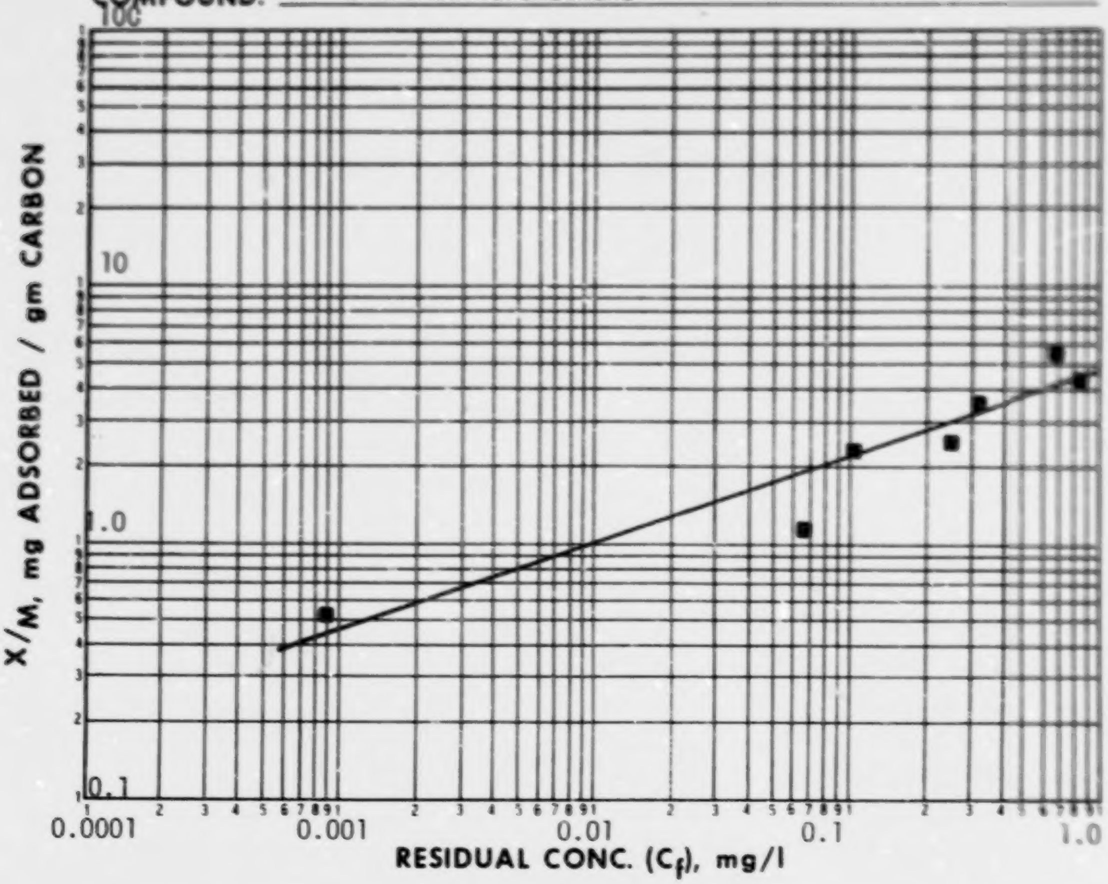
C_0, mg/l	
1.0	210
0.1	45
0.01	9.9

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G. C. Purge and Trap

REMARKS:

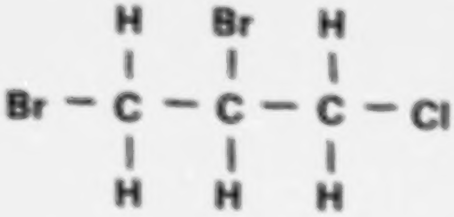
COMPOUND: Dibromochloromethane



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	C_o-C_f=X	X/M	C_f	C_o-C_f=X	X/M
0	1.000								
38	0.829	0.171	4.45						
58	0.677	0.323	5.59						
192	0.308	0.692	3.60						
289	0.254	0.746	2.59						
385	0.101	0.899	2.34						
769	0.066	0.934	1.21						
1923	0.0009	0.9991	0.520						

COMPOUND: 1,2-Dibromo-3-chloropropane

STRUCTURE:



$$\begin{array}{ccccccc} & H & & Br & & H & \\ & | & & | & & | & \\ Br - & C & - & C & - & C & - Cl \\ & | & & | & & | & \\ & H & & H & & H & \end{array}$$

FORMULA: $C_3H_6Br_2Cl$ **MOL. WT.** 235.34

FREUNDLICH PARAMETERS	pH		
	5.3		
K	53		
1/n	0.47		
Corr. Coef. r	0.99		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	53		
0.1	18		
0.01	6.0		
0.001	2.0		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	50	160	490
0.1		15	48
0.01			4.4

GRANULAR CARBON COLUMN

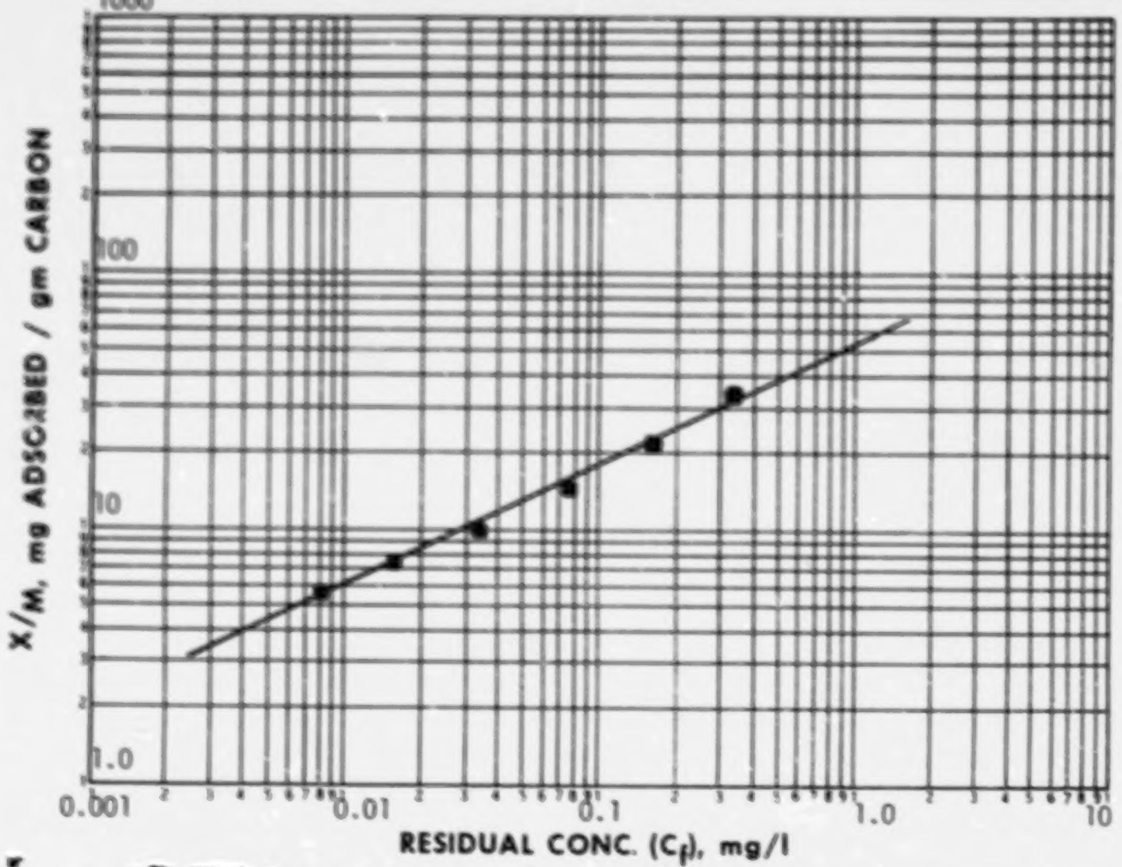
C_o, mg/l	
1.0	19
0.1	5.6
0.01	1.7

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G. C. - Purge and Trap

REMARKS:

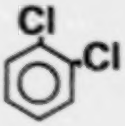
COMPOUND: 1,2-Dibromo-3-chloropropane



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	0.996								
19	0.329	0.667	34.7						
39	0.179	0.817	21.2						
58	0.077	0.918	15.9						
96	0.032	0.964	10.0						
135	0.016	0.980	7.28						
173	0.008	0.988	5.71						

COMPOUND: 1,2-Dichlorobenzene

STRUCTURE:



FORMULA: $C_6H_4Cl_2$ **MOL. WT.** 147.00

FREUNDLICH PARAMETERS	pH		
	5.5		
K	129		
1/n	0.43		
Corr. Coef. r	0.92		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	129		
0.1	47		
0.01	17		
0.001	64		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	19	57	160
0.1		5.2	15
0.01			1.4

GRANULAR CARBON COLUMN

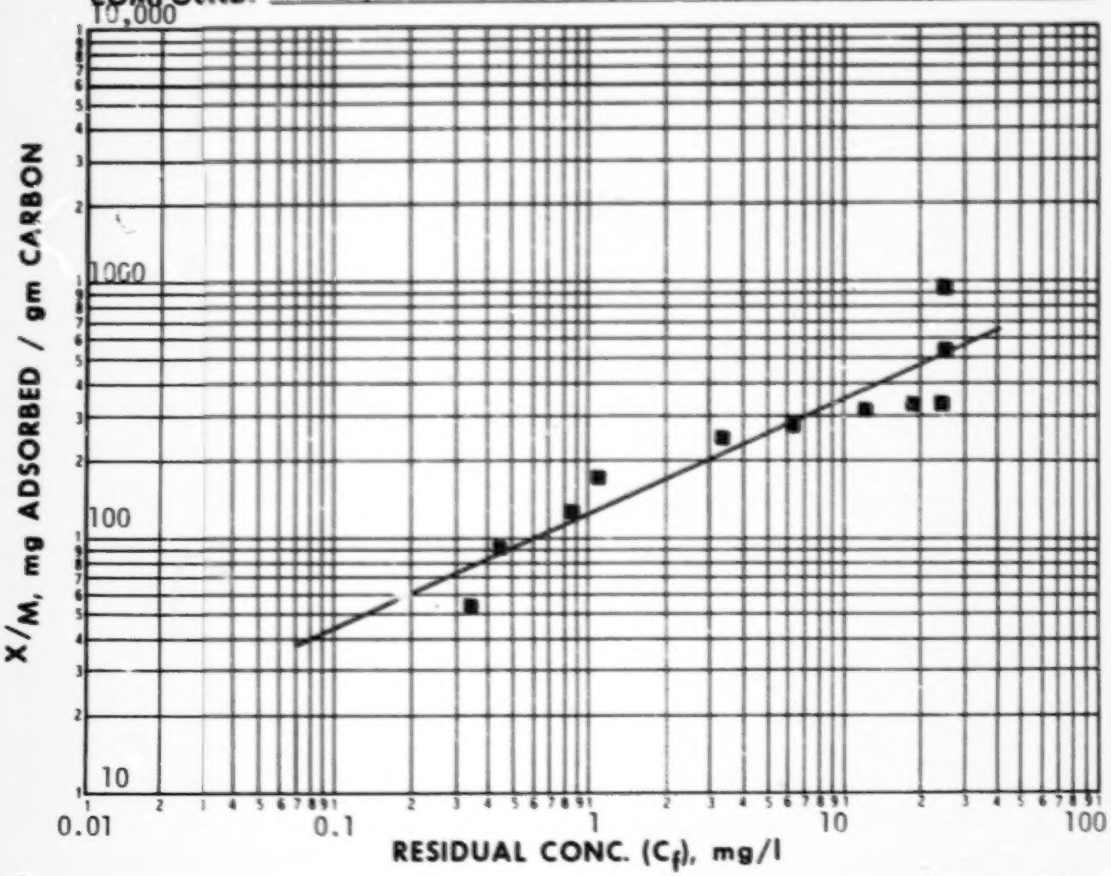
C_o, mg/l	
1.0	7.7
0.1	2.1
0.01	0.6

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 214 nm.

REMARKS:

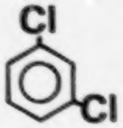
COMPOUND: 1,2-Dichlorobenzene



	■ pH= [illegible].5			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	27.46								
2.5	25.08	2.38	952						
5	24.77	2.69	538						
10	24.20	3.26	326						
25	18.91	8.55	342						
50	11.80	15.66	313						
75	6.15	21.31	284						
100	2.28	25.18	252						
150	1.13	26.33	176						
200	0.86	26.60	133						
300	0.44	27.02	90						
500	0.33	27.13	54						

COMPOUND: 1,3-Dichlorobenzene

STRUCTURE:



FORMULA: $C_6H_4Cl_2$ **MOL. WT.** 147.00

FREUNDLICH PARAMETERS	pH		
	5.1		
K	118.		
1/n	0.45		
Corr. Coef. r	0.86		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	118		
0.1	42		
0.01	15		
0.001	5.1		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	22	68	200
0.1		6.2	19
0.01			1.8

GRANULAR CARBON COLUMN

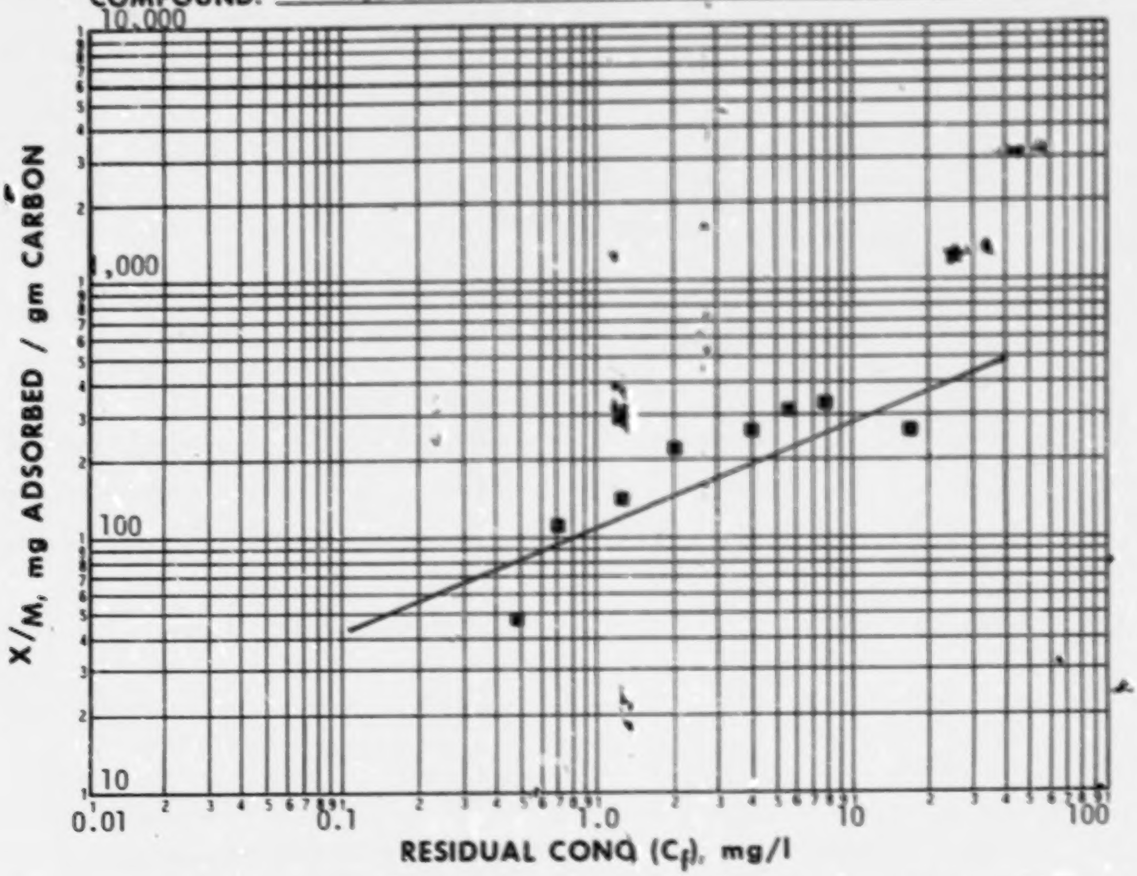
C_o, mg/l	--
1.0	8.5
0.1	2.4
0.01	0.7

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 214 nm

REMARKS:

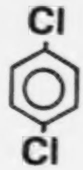
COMPOUND: 1,3-Dichlorobenzene



	● pH= 5.1			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	24.25								
25	17.51	6.74	269.6						
50	7.85	16.4	328						
60	5.73	18.52	308.7						
75	3.96	20.29	270.5						
100	2.04	22.21	222.1						
150	1.31	22.94	152.9						
200	0.70	23.55	117.7						
500	0.48	23.77	47.5						

COMPOUND: 1,4-Dichlorobenzene

STRUCTURE:



FORMULA: $C_6H_4Cl_2$ **MOL. WT.** 147.00

FREUNDLICH PARAMETERS	pH		
	5.1		
K	121		
1/n	0.47		
Corr. Coef. r	0.94		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	121		
0.1	41		
0.01	14		
0.001	4.6		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	22	73	220
0.1		6.6	22
0.01			2.0

GRANULAR CARBON COLUMN

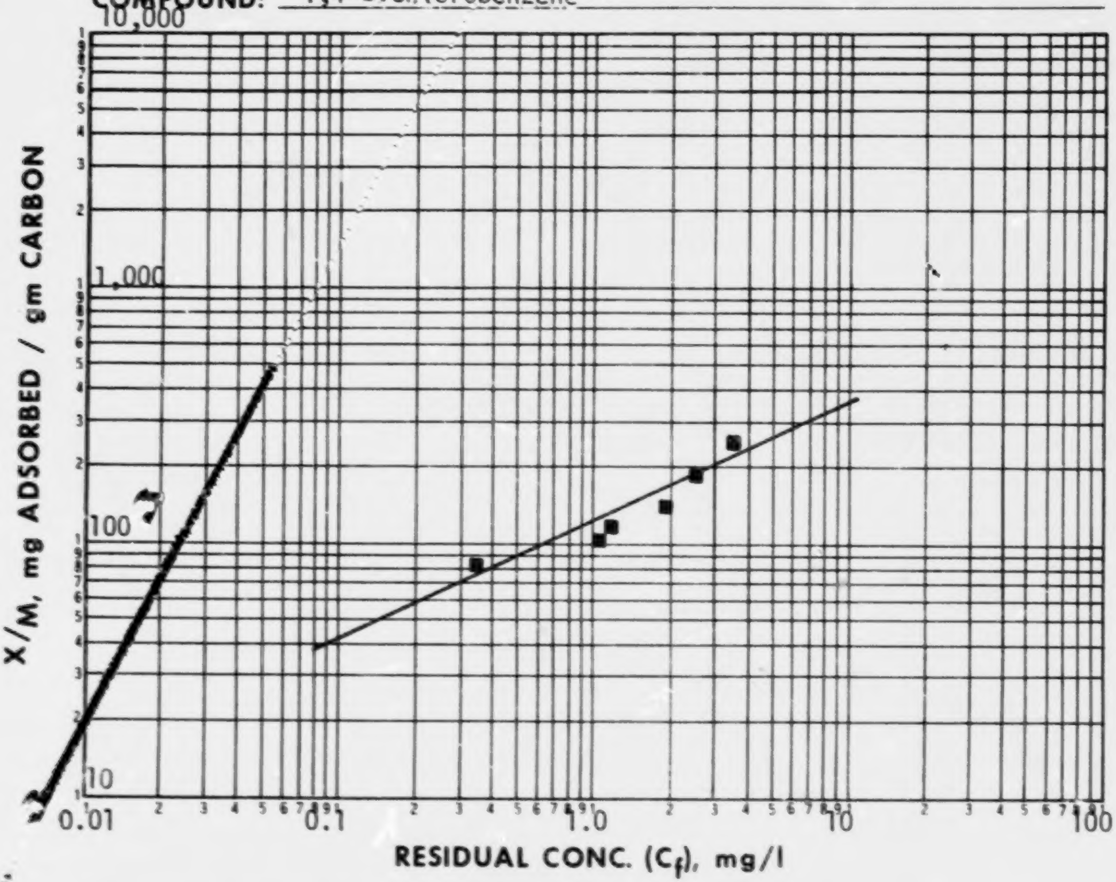
C_o, mg/l	
1.0	8.3
0.1	2.5
0.01	0.7

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 223 nm

REMARKS:

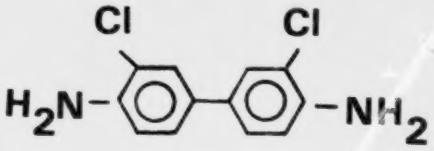
COMPOUND: 1,4-Dichlorobenzene



	■ pH= 5.1			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	16.71								
50	3.48	13.23	264.6						
75	2.55	14.16	188.8						
100	1.94	14.77	147.7						
125	1.19	15.52	124.16						
150	1.03	15.68	104.5						
200	0.33	16.38	81.9						

COMPOUND: 3,3-Dichlorobenzidine

STRUCTURE:



FORMULA: $C_{12}H_{10}Cl_2N_2$ **MOL. WT.** 253.13

FREUNDLICH PARAMETERS	pH		
	All Data Pooled		
K	300		
1/n	0.20		
Corr. Coef. r	0.92		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	300		
0.1	190		
0.01	120		
0.001	73		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	4.8	8.3	13
0.1		0.8	1.3
0.01			0.1

GRANULAR CARBON COLUMN

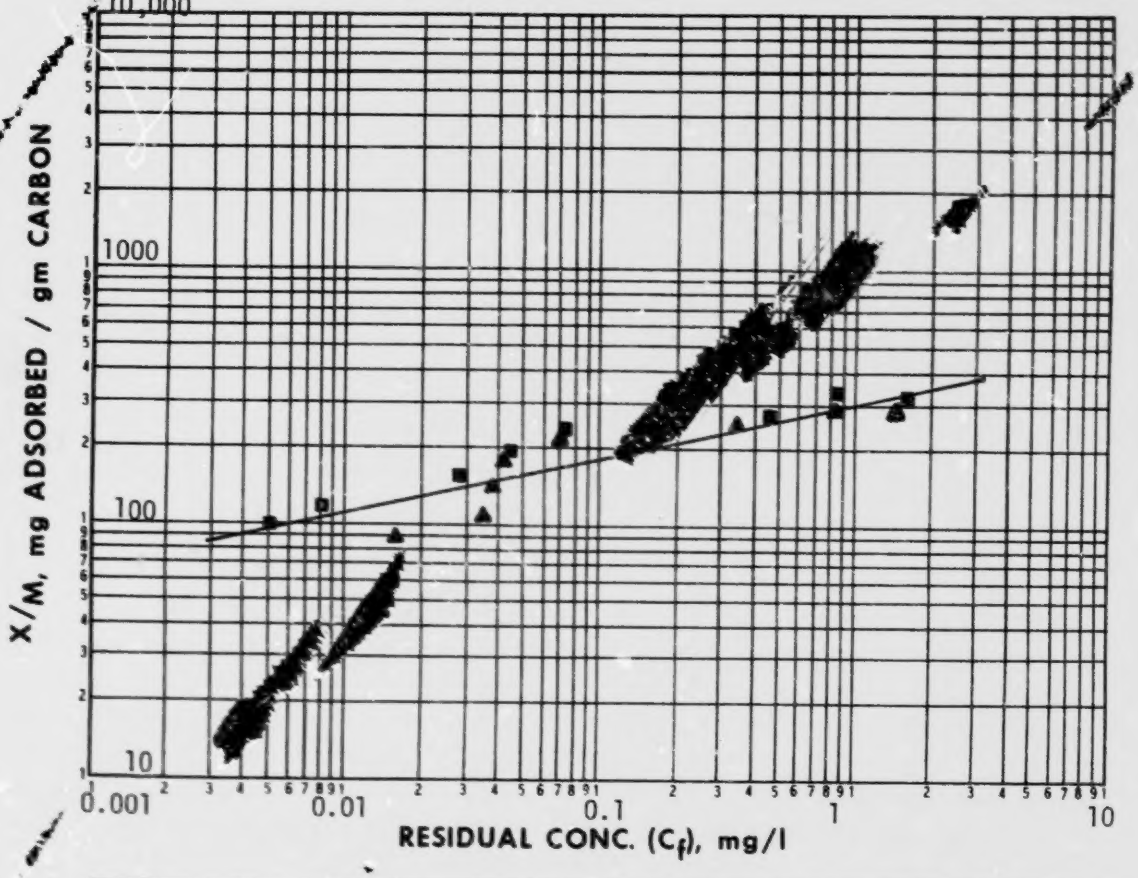
C_o, mg/l	
1.0	3.3
0.1	0.5
0.01	0.1

(a) Carbon doses in mg/l for pooled data

ANALYTICAL METHOD: Ultraviolet Spectroscopy 282 nm

REMARKS: OSHA regulated carcinogen

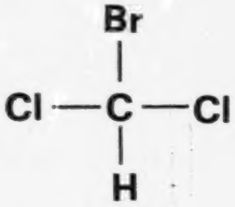
COMPOUND: 3,3-Dichlorobenzidine



	■ pH= 7.2			▲ pH= 9.1			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	2.51			2.28					
2.5	1.70	0.81	324	1.55	0.73	292			
5	0.83	1.68	336	0.81	1.47	294			
7.5	0.46	2.05	273	0.33	1.95	260			
10	0.072	2.44	244	0.070	2.210	221			
12.5	0.044	2.466	197	0.042	2.238	179			
15	0.028	2.482	165	0.038	2.242	149			
20	0.008	2.502	125	0.034	2.246	112			
25	0.005	2.505	100	0.017	2.263	90			

COMPOUND: Dichlorobromomethane

STRUCTURE:



FORMULA: $CHCl_2Br$ **MOL. WT.** 163.83

FREUNDLICH PARAMETERS	pH		
	5.3		
K	7.9		
1/n	0.61		
Corr. Coef. r	1.00		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	7.9		
0.1	1.9		
0.01	0.47		
0.001	0.12		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	500	2,100	8,700
0.1		190	860
0.01			78

GRANULAR CARBON COLUMN

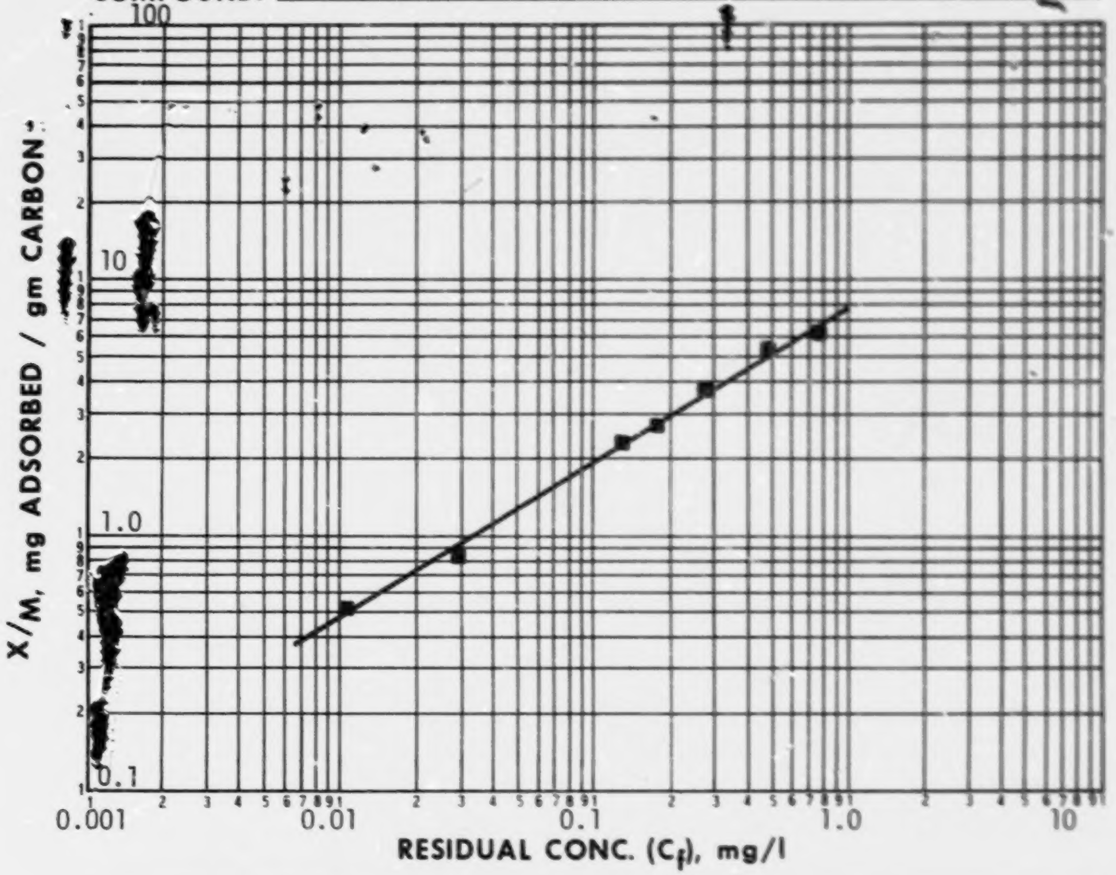
C_o, mg/l	
1.0	130
0.1	52
0.01	21

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G. C. Purge and Trap

REMARKS:

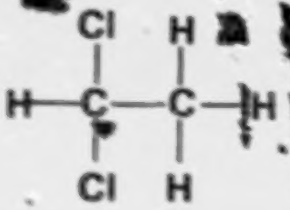
COMPOUND: Dichlorobromomethane



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	1.000								
38	0.762	0.238	6.20						
96	0.479	0.521	5.42						
192	0.277	0.723	3.76						
289	0.183	0.817	2.83						
385	0.134	0.866	2.25						
1154	0.029	0.971	0.841						
1923	0.011	0.990	0.514						

COMPOUND: 1,1-Dichloroethane

STRUCTURE:


$H-\overset{Cl}{\underset{Cl}{C}}-\overset{H}{\underset{H}{C}}-H$

FORMULA: $C_2H_4Cl_2$ **MOL. WT.** 98.96

FREUNDLICH PARAMETERS	pH		
	5.3		
K	1.79		
1/n	0.53		
Corr. Coef. r	0.96		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	1.8		
0.1	0.52		
0.01	0.15		
0.001	0.04		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON
C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	1.00	6,500	22,000
0.1		600	2,200
0.01			200

GRANULAR CARBON COLUMN

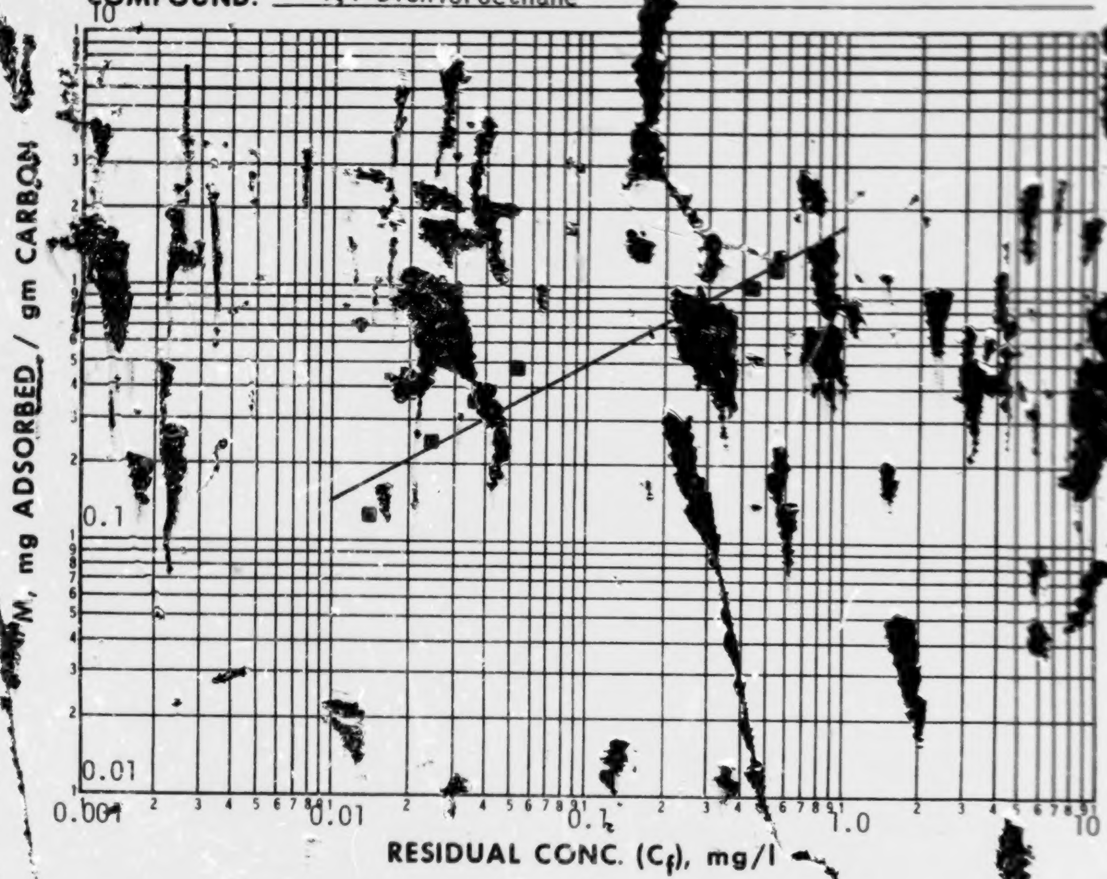
C_o, mg/l	
1.0	560
0.1	190
0.01	70

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G.C - Purge and Trap

REMARKS:

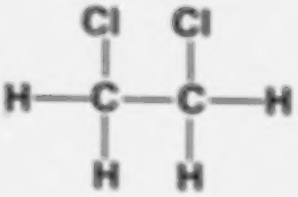
COMPOUND: 1,1-Dichloroethane



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=$	X/M
0	1.000								
385	0.532	0.468	1.22						
577	0.422	0.578	1.00						
1923	0.052	0.948	0.493						
2692	0.036	0.964	0.358						
3846	0.023	0.977	0.254						
7692	0.014	0.986	0.128						

COMPOUND: 1,2-Dichloroethane

STRUCTURE:



FORMULA: C_2H_4C[illegible] **MOL. WT.** 98.96

FREUNDLICH PARAMETERS	pH		
[illegible]	5[illegible]		
[illegible]	[illegible]		
[illegible]	0.[illegible]		
[illegible] coeff r	0.9[illegible]		
INITIAL CONC. mg/l	ADSORPTION CAPACITY mg/gm		
1.0	3.6		
0.1	0.52		
0.01	0.08		
0.001	0.01		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	1700	13,000	[illegible]5,000
0.1		1,200	[illegible]600
0.01			780

GRANULAR CARBON COLUMN

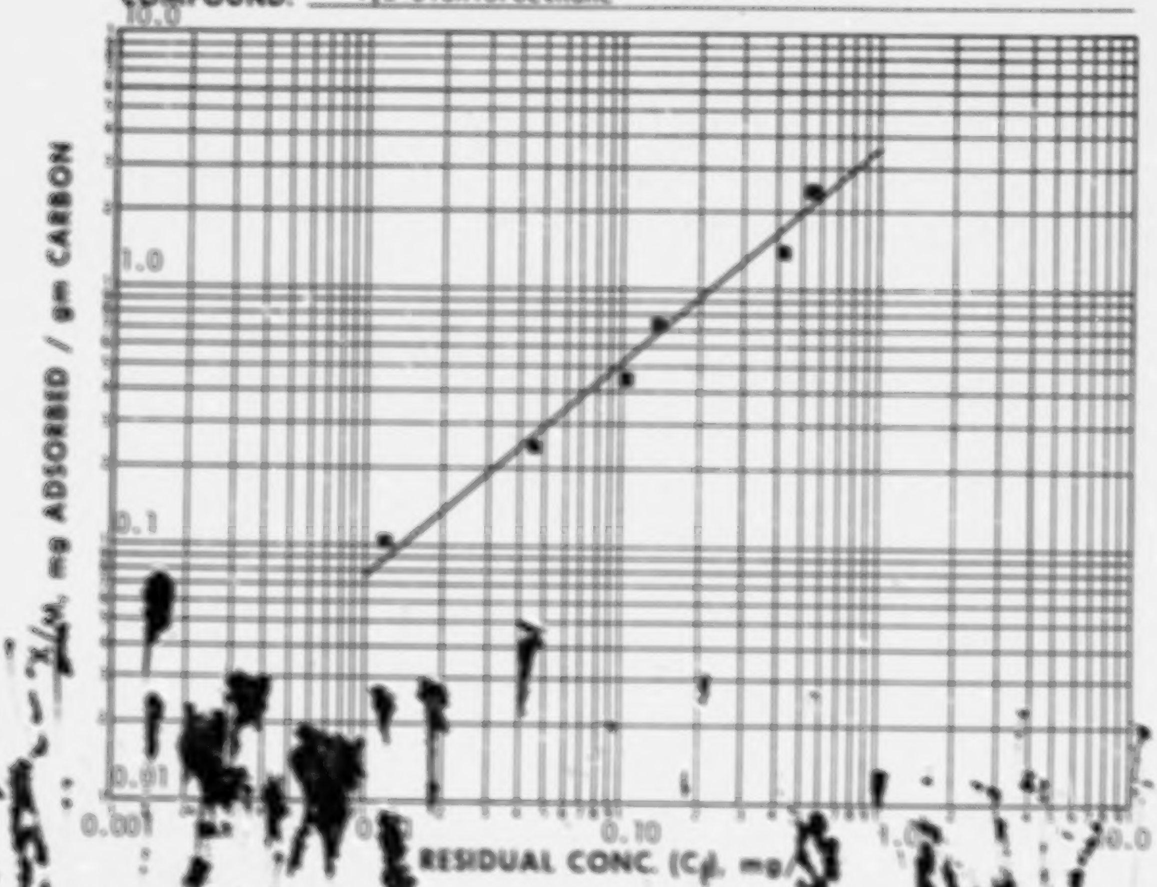
C_o, mg/l	
1.0	280
0.1	190
0.01	[illegible]

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G.C. - Purge and Trap

REMARKS:

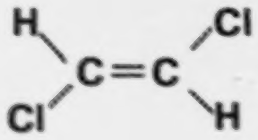
COMPOUND: 1,2-Dichloroethane



	● pH = 5.3			pH?					
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	1.000								
192	0.527	0.473	2.46						
385	0.406	0.594	1.55						
1154	0.144	0.856	0.742						
1923	0.103	0.897	0.466						
3846	0.046	0.954	0.248						
9615	0.012	0.988	0.103						

COMPOUND: 1,2-trans-Dichloroethene

STRUCTURE:



FORMULA: $C_2H_2Cl_2$ **MOL. WT.** 96.94

FREUNDLICH PARAMETERS	pH		
	6.7		
K	3.05		
1/n	0.51		
Corr. Coef. r	0.99		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	3.0		
0.1	0.94		
0.01	0.29		
0.001	0.09		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE-STAGE POWDERED CARBON

C_o, mg/l	C_e, mg/l		
	0.1	0.01	0.001
1.0	950	3,400	11,000
0.1		310	[illegible],100
0.01			100

GRANULAR CARBON COLUMN

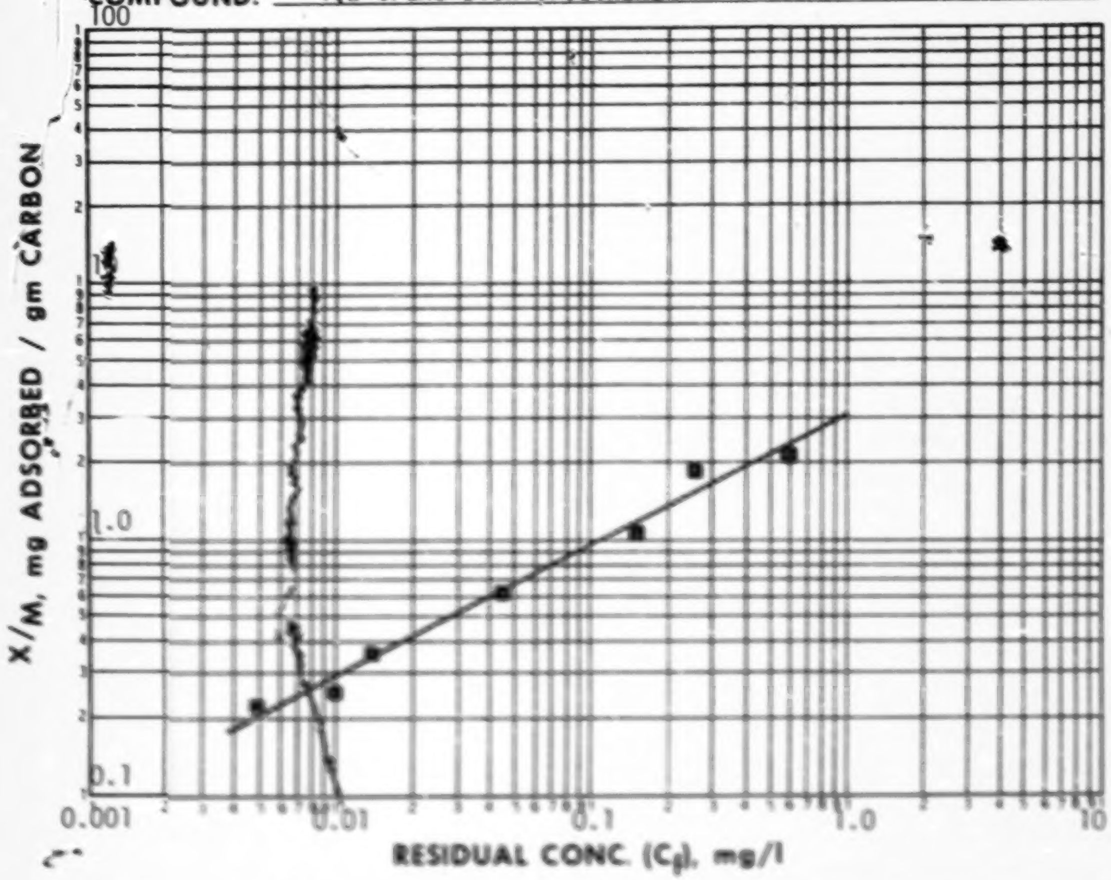
C_o, mg/l	[illegible]
1.0	[illegible]
0.1	[illegible]
0.01	34

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G.C. Purge and Trap

REMARKS:

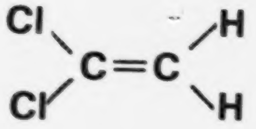
COMPOUND: 1,2-trans-Dichloroethene



CARBON DOSE mg/l	■ pH= 6.7			pH=			pH=		
	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	1000								
192	0.597	0.403	2.10						
385	0.258	0.742	1.93						
769	[illegible]	0.840	1.09						
153	[illegible]	0.956	[illegible]						
269	[illegible]	0.986	0.366						
384	0.009	0.990	0.257						
461	0.0045	0.995	0.216						

COMPOUND: 1,1-Dichloroethene (1,1-Dichloroethylene)

STRUCTURE:



FORMULA: $C_2H_2Cl_2$ **MOL. WT.** 96.94

FREUNDLICH PARAMETERS	pH		
	5.3		
K	4.91		
1/n	0.54		
Corr. Coef. r	0.99		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	4.9		
0.1	1.4		
0.01	0.41		
0.001	0.12		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	640	2,400	8,600
0.1		220	850
0.01			77

GRANULAR CARBON COLUMN

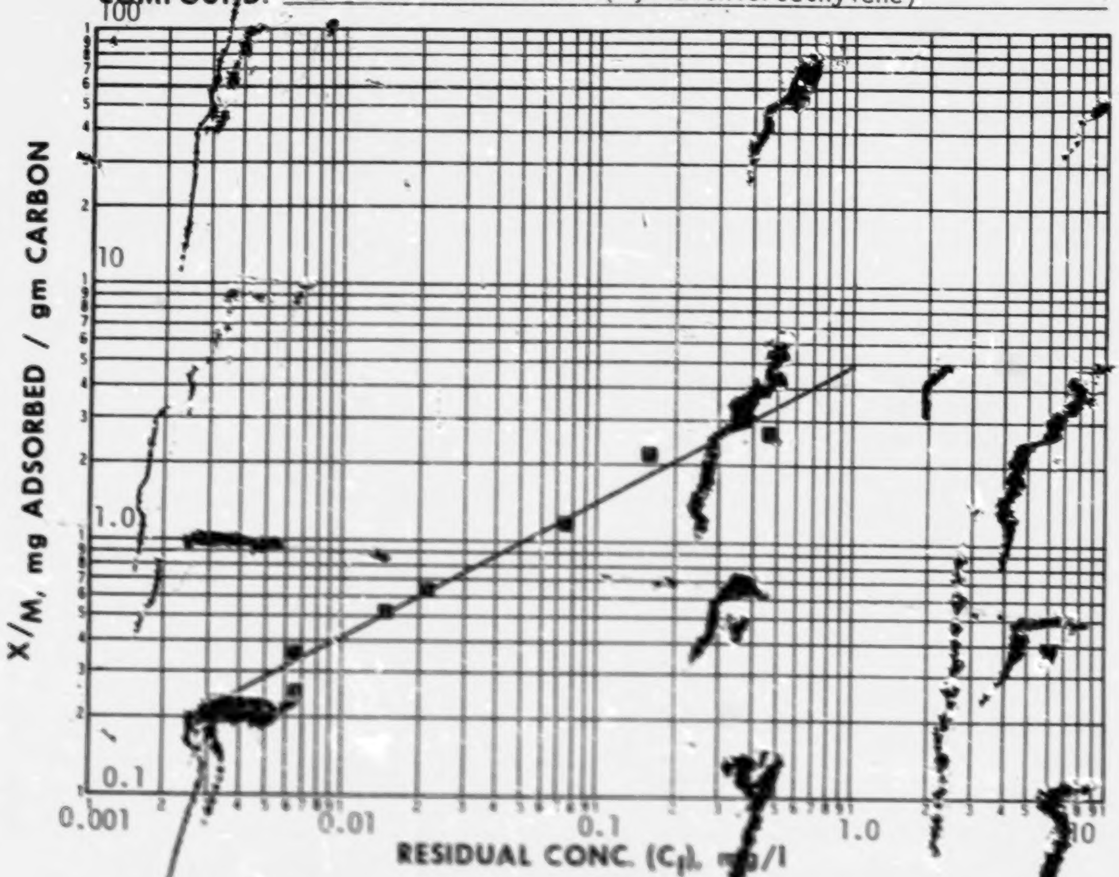
C_o, mg/l	
1.0	200
0.1	70
0.01	24

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G. C. Purge and Trap

REMARKS:

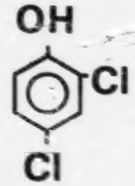
COMPOUND: 1,1-Dichloroethene (1,1-Dichloroethylene)



CARBON DOSE mg/l	■ pH= 5.3			pH=			pH=		
	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	1.000								
192	0.455	0.545	2.83						
385	0.166	0.834	2.17						
769	0.075	0.925	1.20						
1538	0.021	0.979	0.637						
1923	[illegible]	0.984	0.512						
2592	0.0063	0.994	0.369						
3846	0.0065	0.994	0.238						

COMPOUND: 2,4-Dichlorophenol

STRUCTURE:



FORMULA: $C_6H_4OCl_2$ **MOL. WT.** 163.00

FREUNDLICH PARAMETERS	pH		
	3.0	5.3	9.0
K	147	157	141
1/n	0.35	0.15	0.29
Corr. Coef. r	0.96	0.96	0.95
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	147	[illegible]	141
0.1	65	112	72
0.01	29	80	37
0.001	13	57	19

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_o, mg/l	C_f, mg/l		
	0.1	0.01	0.001
1.0	8.0	12	17
0.1		1.1	1.7
0.01			0.2

GRANULAR CARBON COLUMN

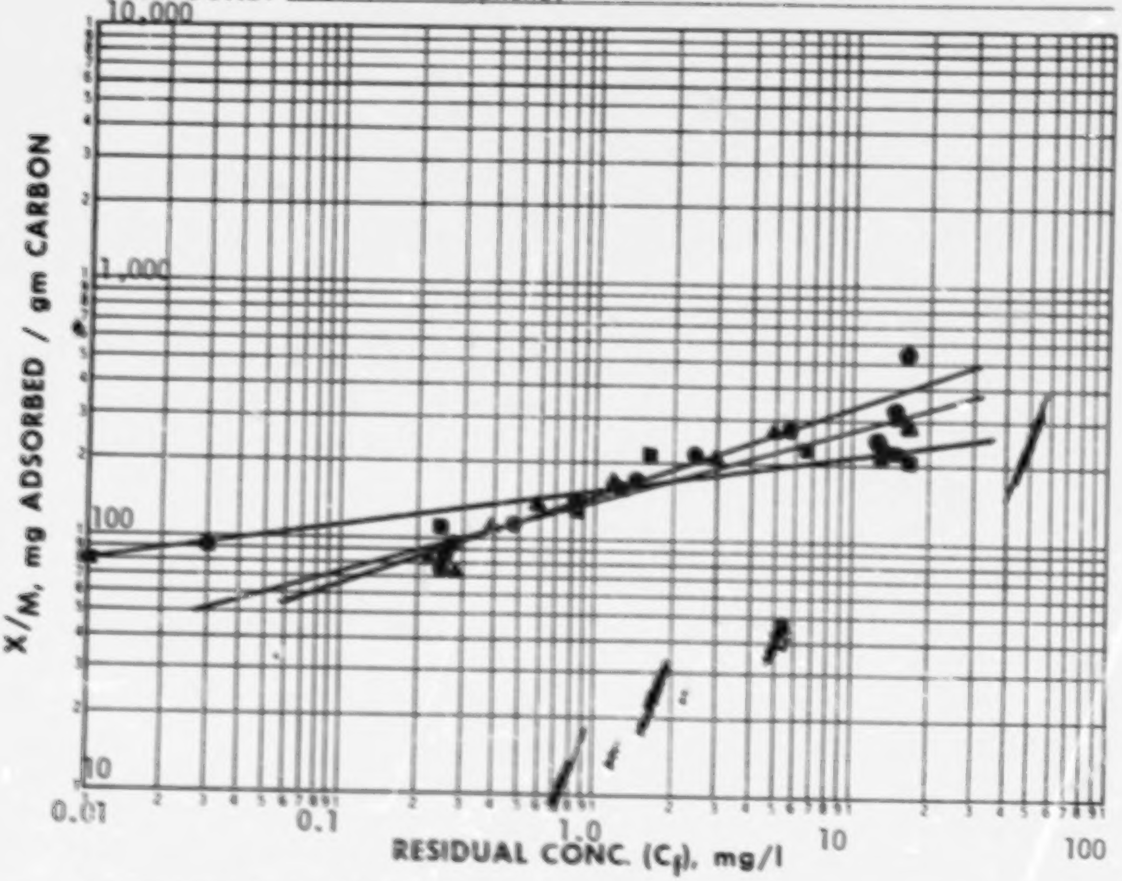
C_o, mg/l	
1.0	6.4
0.1	0.9
0.01	0.1

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 241.2 nm at pH 11

REMARKS:

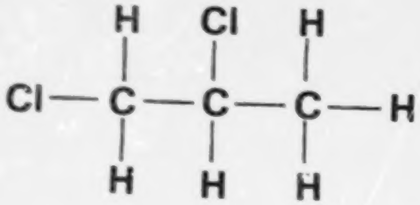
COMPOUND: 2,4-Dichlorophenol



CARBON DOSE mg/l	● pH= 3.0			● pH= 53			▲ pH= 9		
	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	19.50			18.14			18.65		
[illegible]	16.75	2.75	550	17.10	1.04	208	17.21	1.44	288
10	16.19	3.31	331	15.85	2.29	229	15.60	3.05	305
25	12.90	6.60	264	12.63	5.51	220	12.27	6.38	255
50	5.80	13.70	274	6.56	11.58	232	4.97	13.68	274
75	2.54	16.96	226	1.67	16.47	220	2.99	15.66	209
100	1.57	17.93	179	1.26	16.88	169	1.27	17.38	174
125	0.83	18.67	149	0.82	17.32	139	0.59	18.06	144
150	0.49	19.01	127	0.24	17.90	119	0.39	18.26	122
200	0.28	19.22	96	0.03	18.11	91	0.26	18.39	92
225	0.26	19.24	85	0.01	18.13	81	0.22	18.43	82
250	0.25	19.25	77	-	-	-	0.28	18.37	73

COMPOUND: 1,2-Dichloropropane

STRUCTURE:



FORMULA: $C_3H_6Cl_2$ **MOL. WT.** 112.99

FREUNDLICH PARAMETERS	pH		
	5.3		
K	5.86		
1/n	0.60		
Corr. Coef. r	0.98		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	5.9		
0.1	1.5		
0.01	0.37		
0.001	0.09		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	600	2700	11,000
0.1		240	1,100
0.01			96

GRANULAR CARBON COLUMN

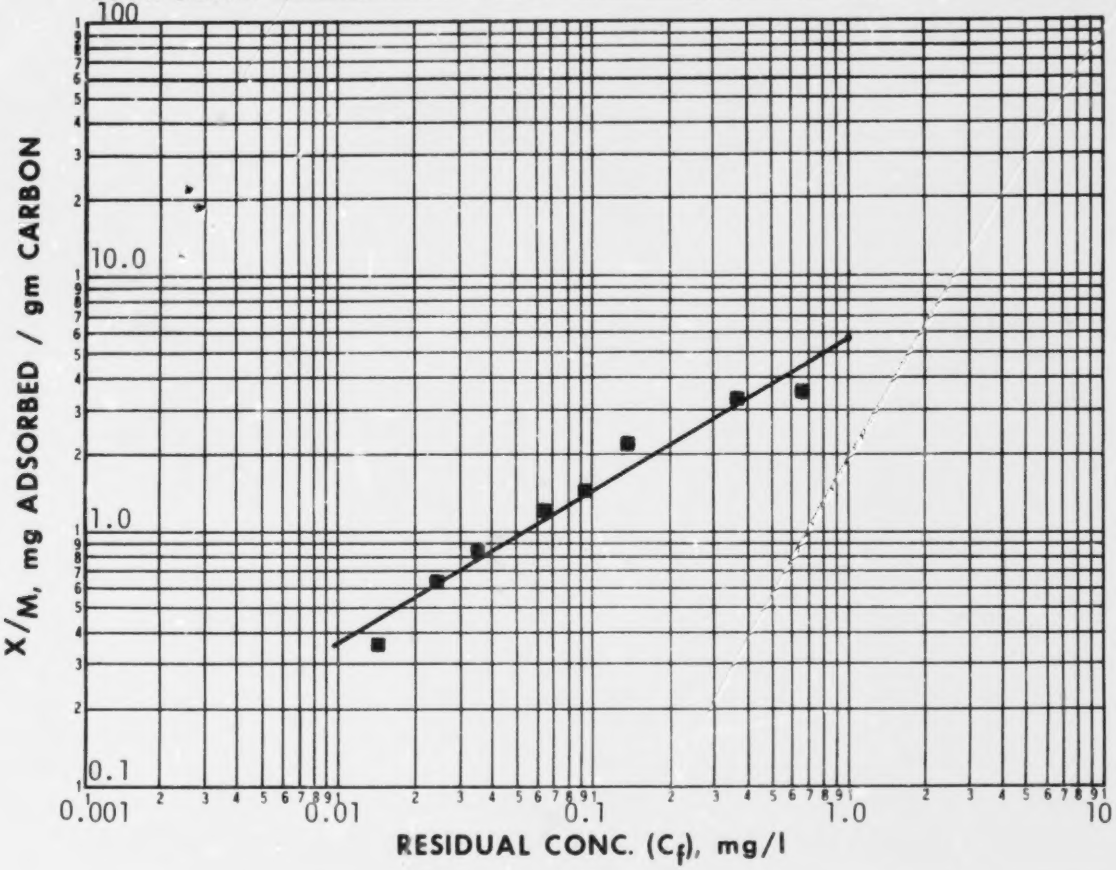
C_o, mg/l	
1.0	170
0.1	68
0.01	27

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G. C. Purge and Trap

REMARKS:

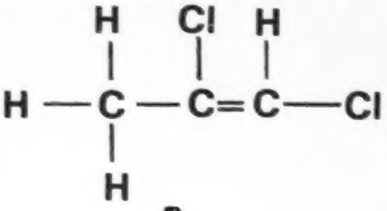
COMPOUND: 1,2-Dichloropropane



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	1.00								
96	0.654	0.346	3.60						
192	0.370	0.630	3.28						
385	0.143	0.857	2.23						
577	0.0916	0.908	1.57						
769	0.0618	0.938	1.22						
1154	0.0352	0.965	0.836						
1538	0.0238	0.976	0.635						
2692	0.0147	0.985	0.366						

COMPOUND: 1,2-Dichloropropene

STRUCTURE:



$$\mathrm{H-\overset{H}{\underset{H}{C}}-\overset{Cl}{C}=\overset{H}{C}-Cl}$$

FORMULA: $C_3H_4Cl_2$ **MOL. WT.** 110.98

FREUNDLICH PARAMETERS	pH		
	5.3		
K	8.21		
1/n	0.46		
Corr. Coef. r	0.98		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	8.2		
0.1	2.8		
0.01	0.97		
0.001	0.33		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	320	1,000	3,000
0.1		93	300
0.01			27

GRANULAR CARBON COLUMN

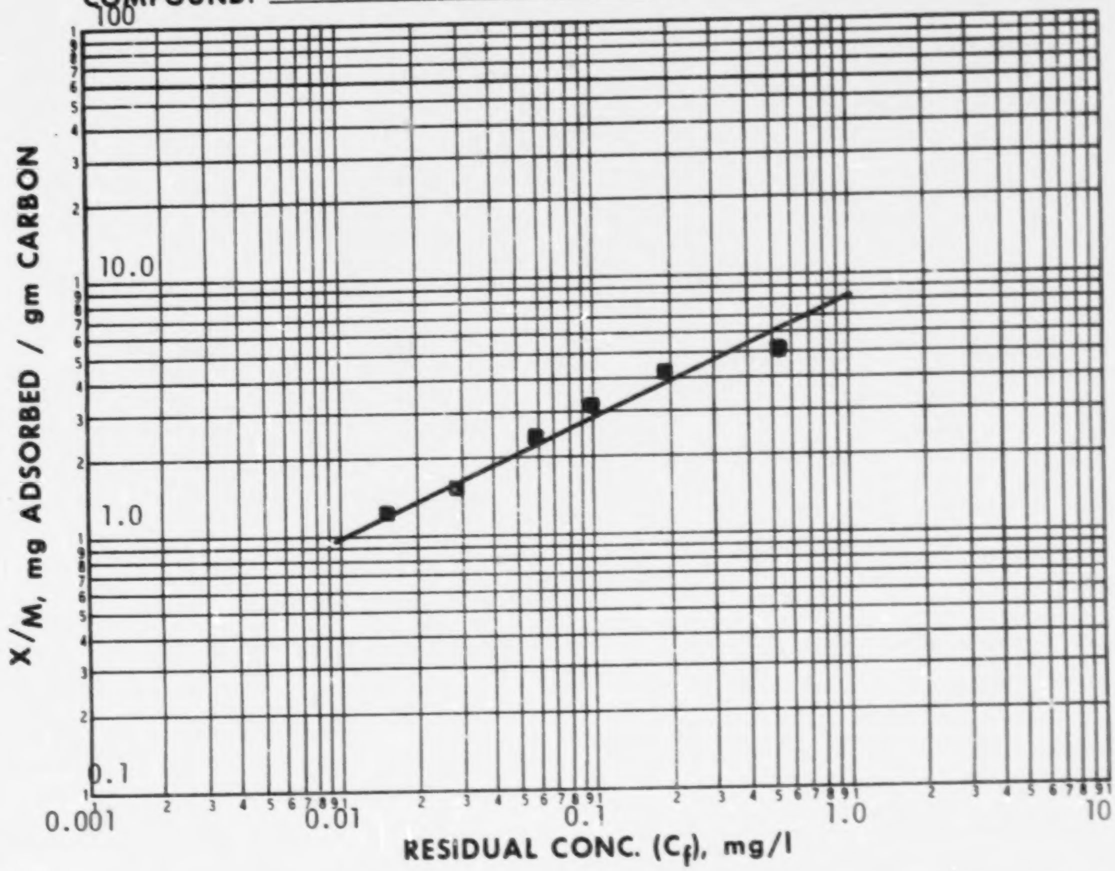
C_o, mg/l	
1.0	120
0.1	35
0.01	10

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G. C. Purge and Trap

REMARKS:

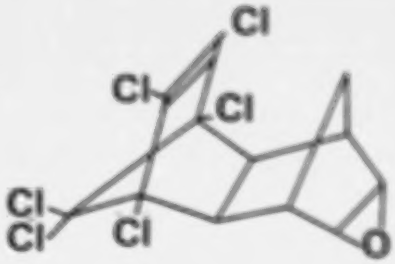
COMPOUND: 1,2-Dichloropropene



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	1,000								
96	0.517	0.483	5.02						
192	0.194	0.806	4.19						
288	0.099	0.901	3.13						
385	0.059	0.941	2.45						
577	0.029	0.971	1.68						
769	0.016	0.984	1.28						
1154	0.012	0.988	0.856						

COMPOUND: Dieldrin

STRUCTURE:



FORMULA. $C_{12}H_8O\,Cl_6$ **MOL. WT.** 380.91

FREUNDLICH PARAMETERS	pH		
	5.3		
K_f	606		
1/n	0.51		
Corr. Coef. r	0.96		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	606		
0.1	185		
0.01	57		
0.001	17		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	4.8	17	56
0.1		1.6	5.5
0.01			0.5

GRANULAR CARBON COLUMN

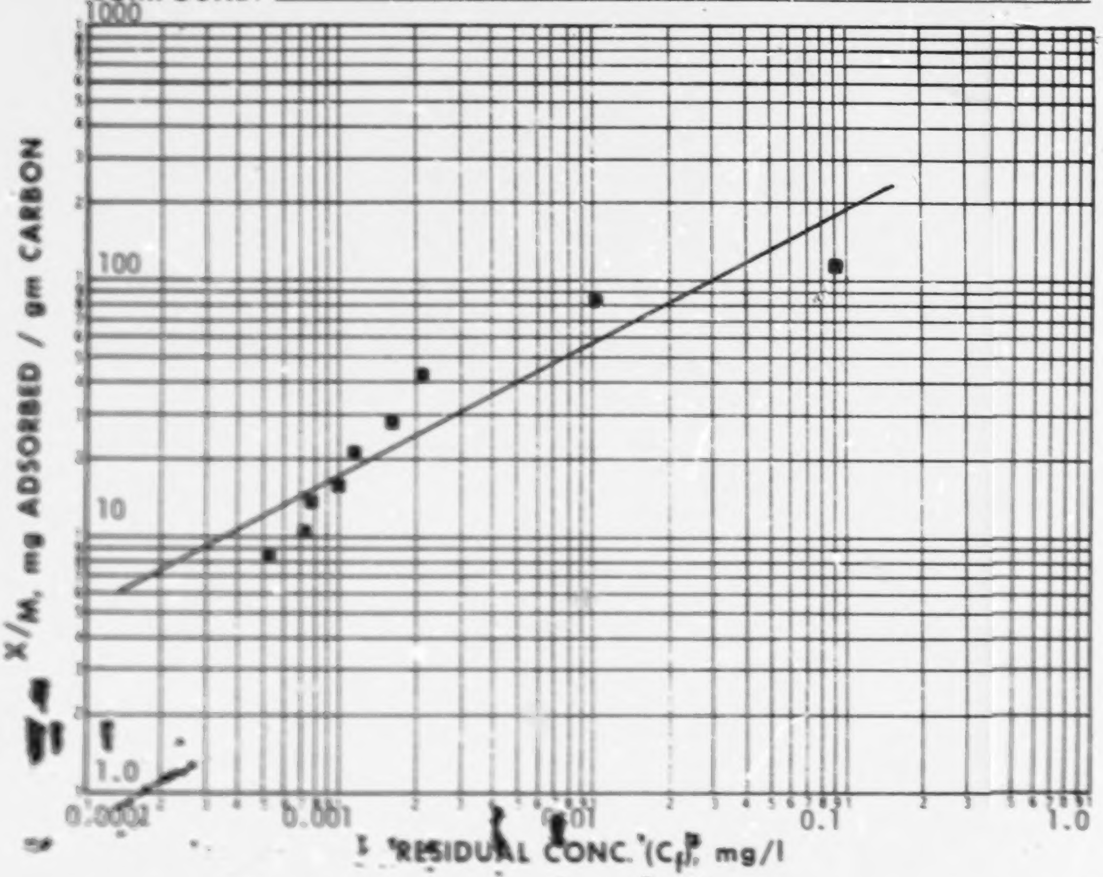
C_o, mg/l	
1.0	1.7
0.1	0.5
0.01	0.2

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent extraction - G.C.

REMARKS:

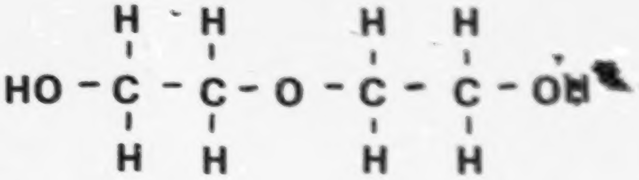
COMPOUND: Dieldrin



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	0.212								
1.0	0.0905	0.1215	122						
2.5	0.0104	0.2016	80.6						
5	0.0021	0.2099	42.0						
7.5	0.0017	0.2103	28.0						
10	0.0012	0.2108	21.1						
12.5	0.0010	0.2110	16.9						
15	0.0008	0.2112	14.1						
20	0.0007	0.2113	10.6						
25	0.0005	0.2115	8.46						

COMPOUND: Diethylene glycol

STRUCTURE:



$$\begin{array}{ccccccccc} & H & & H & & H & & H & \\ & | & & | & & | & & | & \\ HO- & C & - & C & -O- & C & - & C & -OH \\ & | & & | & & | & & | & \\ & H & & H & & H & & H & \end{array}$$

FORMULA: $C_4H_{10}O_3$ **MOL. WT.** 106.12

FREUNDLICH PARAMETERS	pH		
K			
1/n			
Corr. Coef. r			
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l			

GRANULAR CARBON COLUMN

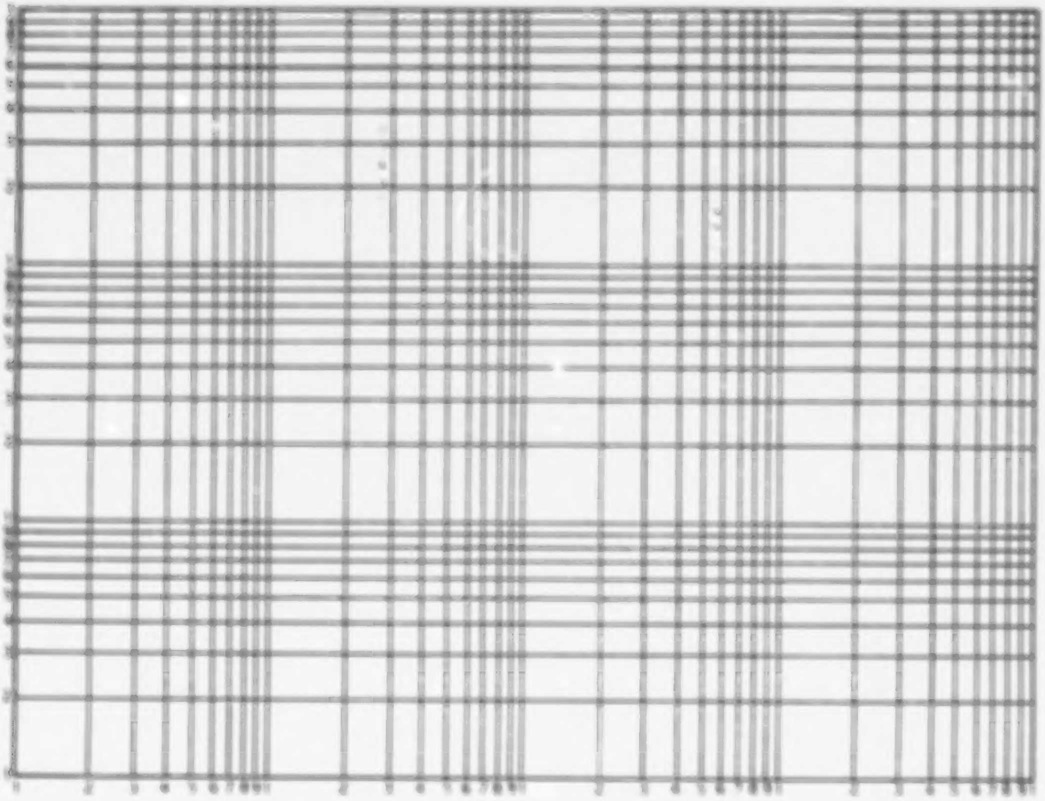
C_o, mg/l	

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Total Organic Carbon

REMARKS: Not adsorbed

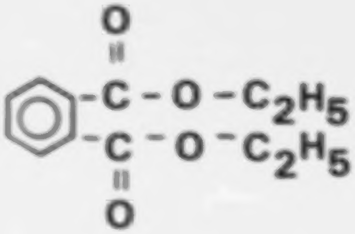
COMPOUND: Diethylene glycol



	pH= 3.0			pH= 7.0			pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	11.8			13.4			11.6		
5	11.0			13.8			11.2		
10	11.2			12.6			11.2		
25	12.0			18.2			11.4		
50	12.0			12.8			11.0		
100	11.0			11.4			11.0		
150	11.0			11.4			10.8		
200	11.0			15.4			11.4		

COMPOUND: Diethyl phthalate

STRUCTURE:



FORMULA: $C_{12}H_{14}O_4$ **MOL. WT.** 222.24

FREUNDLICH PARAMETERS	pH		
	5.4		
K	110		
1/n	0.27		
Corr. Coef. r	0.81		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	110		
0.1	59		
0.01	32		
0.001	17		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	15	31	59
0.1		2.8	5.8
0.01			0.5

GRANULAR CARBON COLUMN

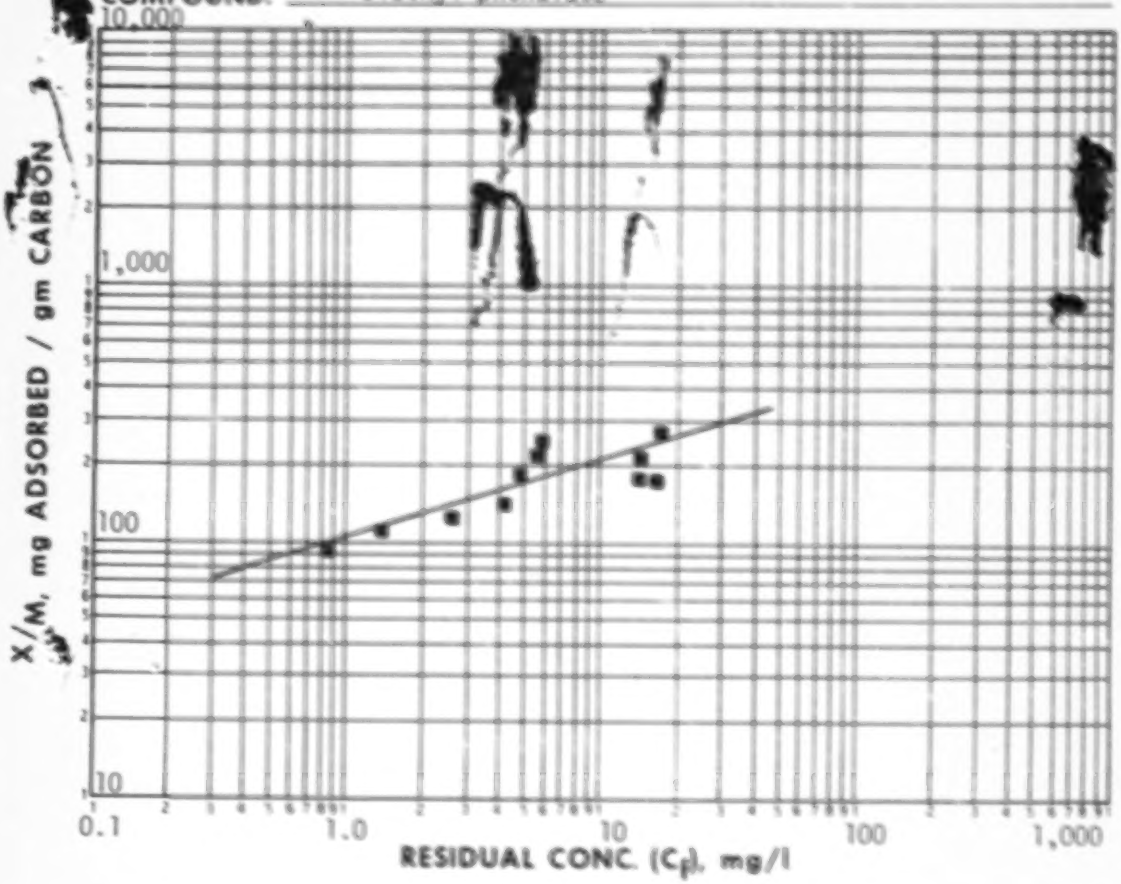
C_o, mg/l	
1.0	9.0
0.1	1.7
0.01	0.3

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 228 nm.

REMARKS:

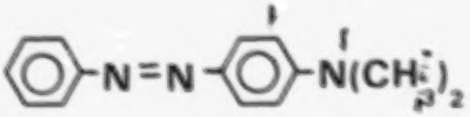
COMPOUND: Diethyl phthalate



	■ pH= 5.4			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	18.88								
4.9	17.47	1.41	283						
9.9	17.11	1.77	179						
19.6	14.65	4.23	216						
24.4	14.41	4.47	183						
49.7	5.89	12.99	261						
59.1	5.64	13.24	224						
72.8	4.88	14.00	192						
99.0	4.13	14.75	149						
121	2.69	16.19	134						
148	1.44	17.44	118						
196	0.86	18.02	92						

COMPOUND: 4-Dimethylaminoazobenzene

STRUCTURE:



FORMULA: $C_{14}H_{15}N_3$ **MOL. WT.** 225.3

FREUNDLICH PARAMETERS	pH		
	7.0		
K	249		
1/n	0.24		
Corr. Coef. r	0.96		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	249		
0.1	140		
0.01	83		
0.001	48		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	6.3	12	21
0.1		1.1	2.1
0.01			0.2

GRANULAR CARBON COLUMN

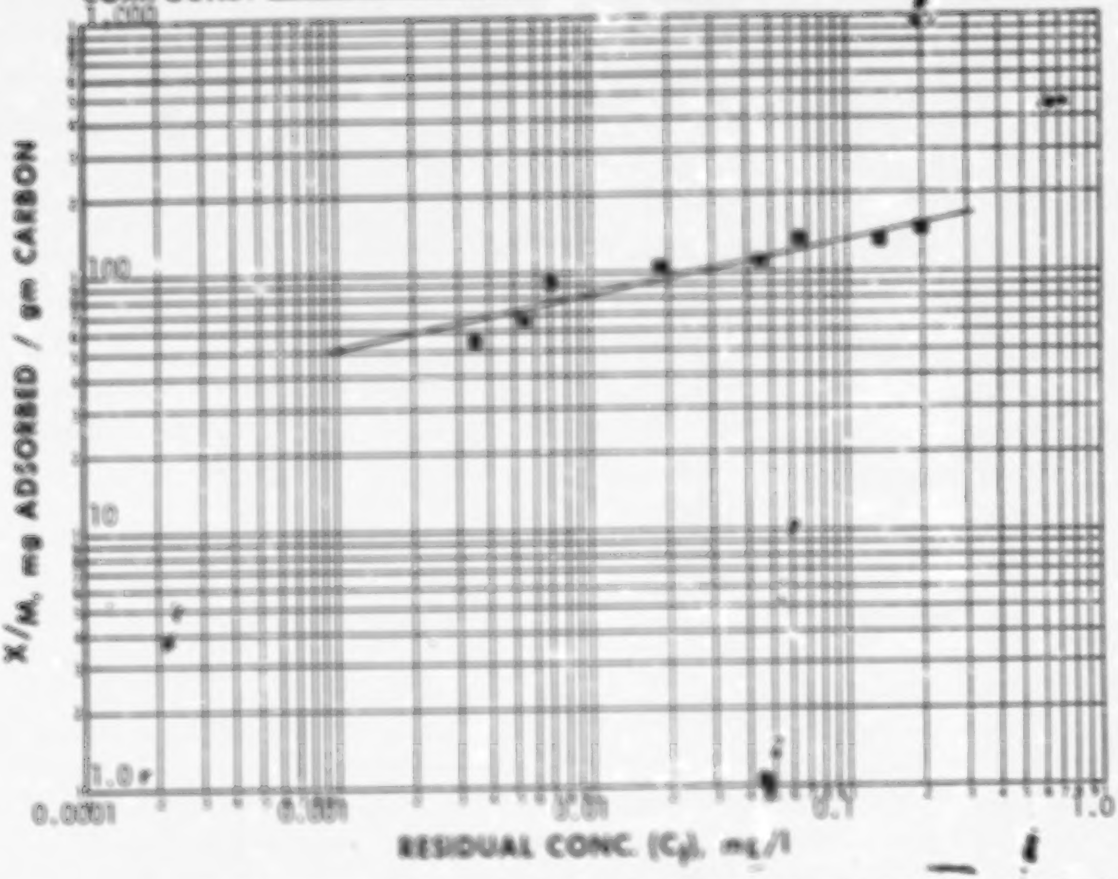
C_o, mg/l	
1.0	4.0
0.1	0.71
0.01	0.12

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Visible Spectroscopy 450 nm

REMARKS: OSHA regulated carcinogen

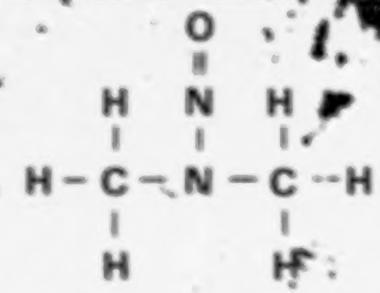
COMPOUND: 4-Dimethylaminoazobenzene



	● pH= 7.0			pH=			pH=		
CARBON DOSE mg/l	[illegible]	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	[illegible]280								
0.5	0.198	0.082	164						
1.0	0.138	0.142	142						
1.5	0.065	0.215	143						
2.0	0.045	0.235	118						
2.5	0.019	0.261	104						
3.0	0.007	0.273	91						
4.0	0.0063	0.275	68.7						
5.0	0.0035	0.276	55.3						

COMPOUND: N-Dimethylnitrosamine

STRUCTURE:



FORMULA: $(CH_3)_2NNO$ **MOL. WT.** 74.08

FREUNDLICH PARAMETERS	pH		
	7.5		
K	6.8×10^{-5}		
1/n	6.6		
Corr. Coef. r	0.62		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	250		
1.0	6.8×10^{-5}		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

	C_f, mg/l		
C_o, mg/l	0.1	0.01	0.001
1.0	>100,000	>100,000	>100,000
0.1		>100,000	>100,000
0.01			

GRANULAR CARBON COLUMN

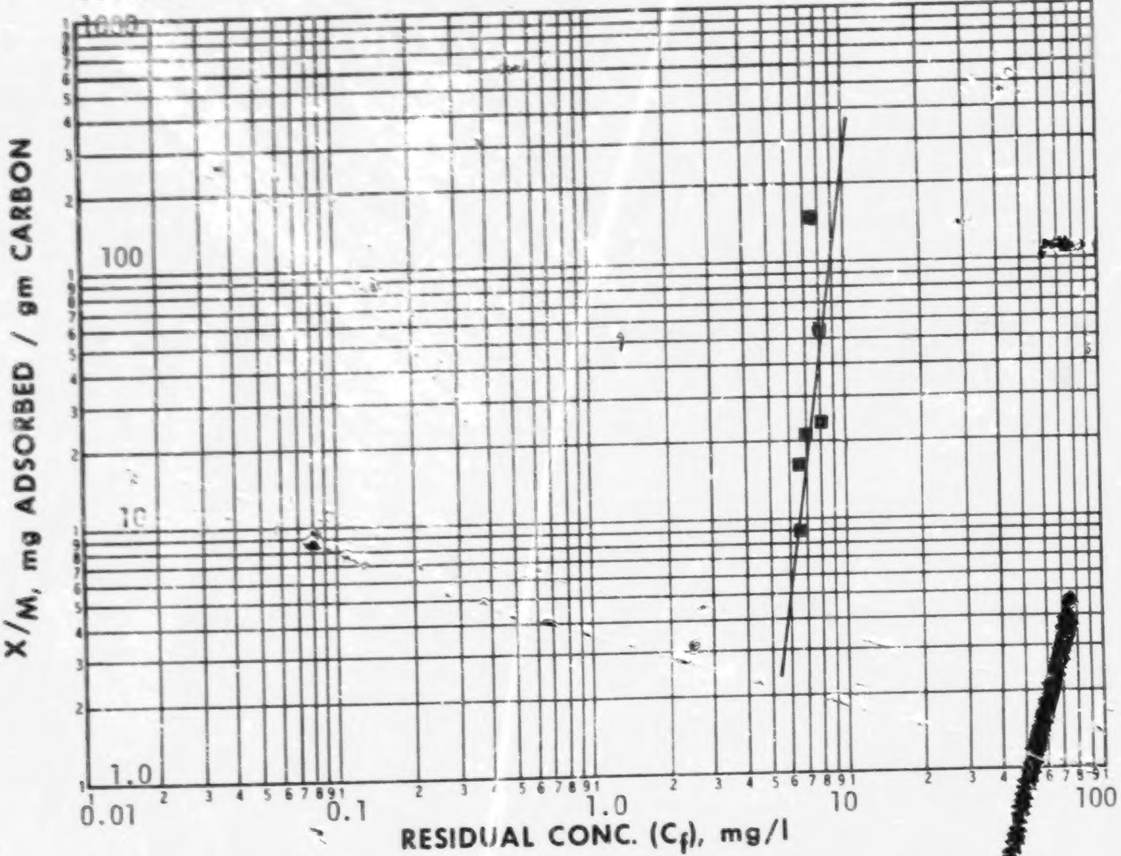
C_o, mg/l	
1.0	>100,000
0.1	>100,000
0.01	>100,000

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent Extraction - G.C.

REMARKS: OSHA regulated carcinogen.

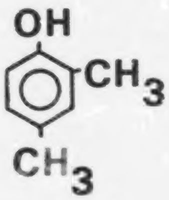
COMPOUND: N-Dimethylnitrosamine



	■ pH= 7.5			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	9.0								
9.2	7.5	1.5	163						
18.4	8.0	1.0	54						
41.2	8.0	1.0	24						
96.0	7.0	2.0	21						
146.4	6.5	2.5	17						
288.0	6.5	2.5	9						

COMPOUND: 2,4-Dimethylphenol

STRUCTURE:



FORMULA: $C_8H_{10}O$ **MOL. WT.** 122.17

FREUNDLICH PARAMETERS	pH		
	3.0	5.8	9.0
K	78	70	108
1/n	0.44	0.44	0.33
Corr. Coef. r	0.93	0.92	0.93
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	78	70	108
0.1	28	25	50
0.01	10	9.1	23
0.001	3.8	3.3	11

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	36	110	300
0.1		98	30
0.01			2.7

GRANULAR CARBON COLUMN

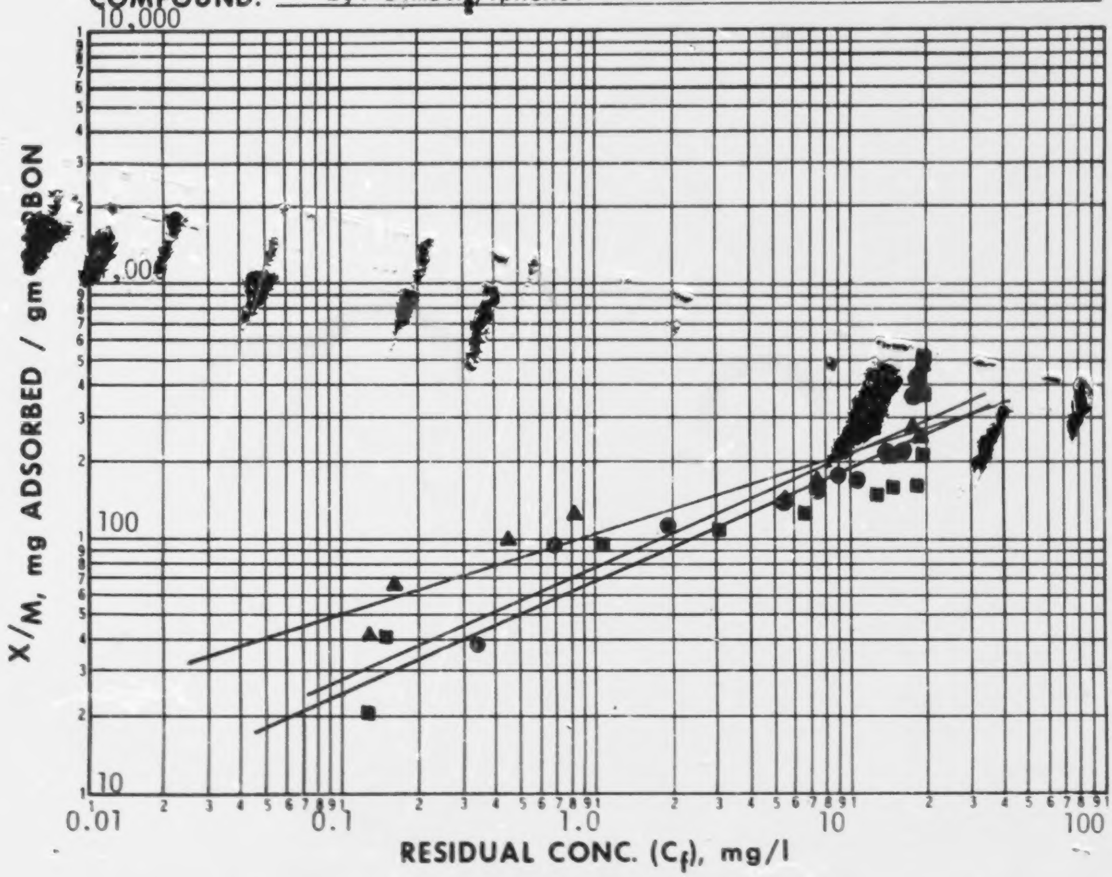
C_o, mg/l	
1.0	14
0.1	4.0
0.01	1.0

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 238 nm at pH 11.

REMARKS:

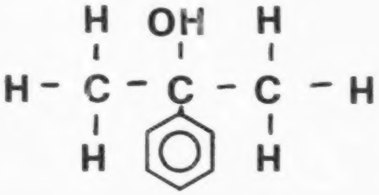
COMPOUND: 2,4-Dimethylphenol



	● pH= 3.0			■ pH= 5.8			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	19.88			20.36			20.48		
1				19.85	0.51	510			
2.5	18.80	1.08	432	19.42	0.94	376	19.25	1.23	492
5.0	18.02	1.86	372	19.28	1.08	216	19.19	1.29	258
10				18.64	1.72	172	17.62	2.86	286
15	16.49	3.39	226						
25	14.36	5.52	221	16.06	4.30	172	15.36	5.12	205
[illegible]	11.04	8.84	177	12.19	8.17	163	9.06	11.42	228
60	[illegible]	10.82	180						
75	[illegible]	12.39	165				7.27	13.21	176
100	[illegible]	14.39	144	6.66	13.7	137	5.46	15.02	150
150	1.95	17.93	120	3.05	17.31	11[illegible]	0.83	19.65	131
200	0.70	19.18	96	1.14	19.22	96	[illegible]	20.02	100
300							0.17	20.31	68
500	0.34	19.54	39	0.16	20.20	40	0.13	20.35	41
1000				0.13	20.23	20			

COMPOUND: Dimethylphenylcarbinol

STRUCTURE:



FORMULA: $C_9H_{12}O$ **MOL. WT.** 136.20

FREUNDLICH PARAMETERS	pH		
	3.0	pH 7 and 9 pooled	
K	110	210	
1/n	0.60	0.34	
Corr. Coef. r	0.98	0.98	
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	420	460	
1.0	110	210	
0.1	27	97	
0.01	6.7	44	

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	9.0	21	46
0.1		1.9	4.5
0.01			0.41

GRANULAR CARBON COLUMN

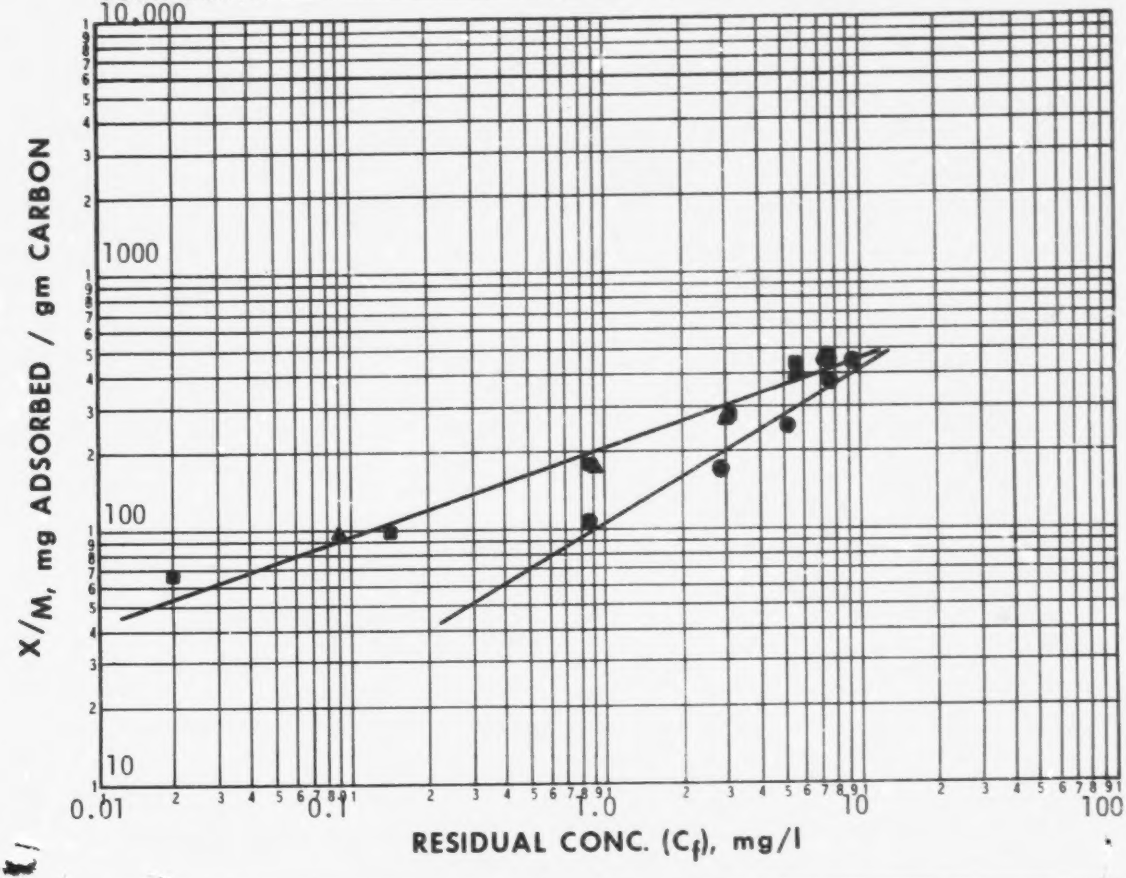
C_o, mg/l	
1.0	4.7
0.1	1.0
0.01	0.2

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 244 nm

REMARKS:

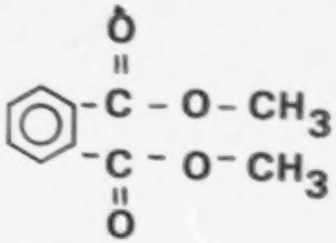
COMPOUND: Dimethylphenylcarbinol



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	11.64			10.00			9.69		
5	9.37	2.27	454	7.64	2.36	472	7.37	2.32	464
10	7.85	3.79	379	5.66	4.34	434	5.72	3.97	397
25	5.22	6.42	257	3.08	6.92	277	3.02	6.67	267
50	2.97	8.67	173	0.88	9.12	182	0.92	8.77	175
100	0.88	10.8	108	0.15	9.85	99	0.09	9.60	96
150				0.02	9.98	67			

COMPOUND: Dimethyl phthalate

STRUCTURE:



FORMULA: $C_{10}H_{10}O_4$ **MOL. WT.** 194.18

FREUNDLICH PARAMETERS	pH		
	All data pooled		
K	97		
1/n	0.41		
Corr. Coef. r	0.93		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	250		
1.0	97		
0.1	38		
0.01	15		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	24	67	180
0.1		6.1	17
0.01			1.6

GRANULAR CARBON COLUMN

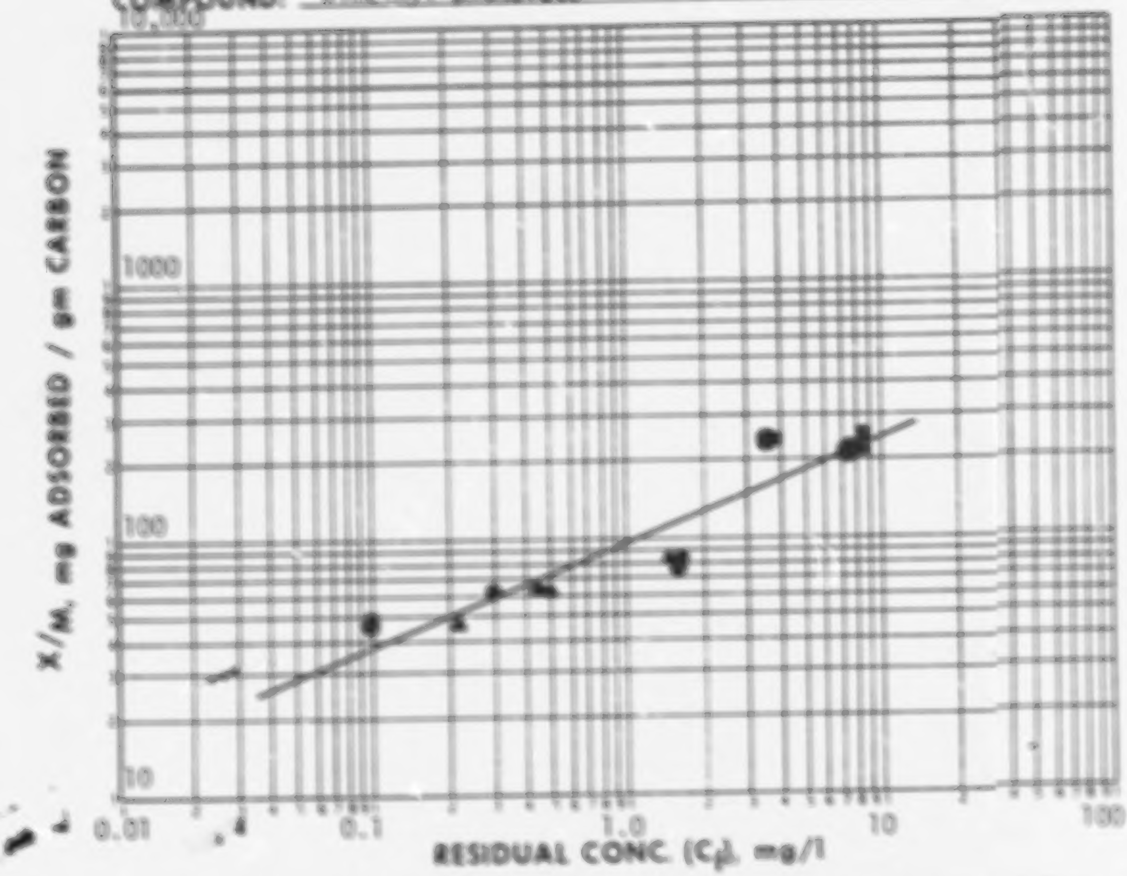
C_o, mg/l	
1.0	[illegible].9
0.1	2.6
0.01	0.7

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 230 nm

REMARKS:

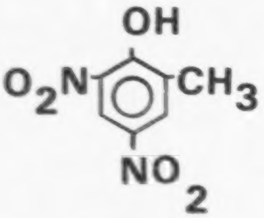
COMPOUND: Dimethyl phthalate



	● pH= 3.0			■ pH= 7.0			▲ pH 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	C_o-C	X/M
0	9.50			9.90			9.60		
5				8.65	1.25	250	8.50	1.1	220
10	7.40	2.10	210	7.65	2.25	225	7.50	2.1	210
25	3.55	5.95	238	3.90	6.00	240	3.65	5.9	238
100	1.70	7.80	78	1.67	8.23	82	1.55	9.0	83
150	0.30	9.20	61	0.43	9.47	63	0.50	9.1	61
200	0.10	9.40	47	0.10	9.80	49	0.22	9.3	47

COMPOUND: 4,6-Dinitro-o-cresol

STRUCTURE:



FORMULA: $C_7H_6N_2O_5$ **MOL. WT.** 198.14

FREUNDLICH PARAMETERS	pH		
	3.0	5.2	9.0
K	237	169	42.74
1/n	0.32	35	0.90
Corr. Coef. r	0.97	0.98	0.99
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	237	169	.43
0.1	114	76	5.3
0.01	55	34	0.7
0.001	26	15	0.1

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	12	28	63
0.1		2.6	6.2
0.01			0.6

GRANULAR CARBON COLUMN

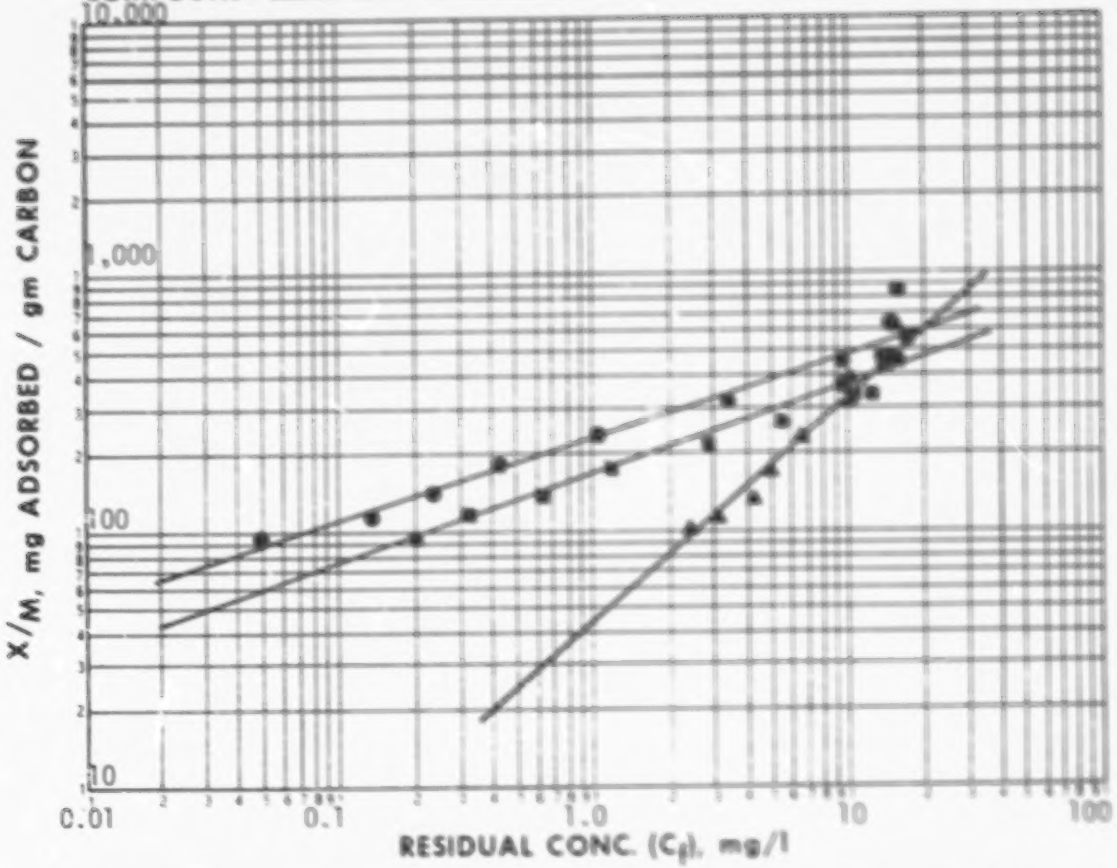
C_o, mg/l	
1.0	6.0
0.1	1.3
0.01	0.3

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 271 nm

REMARKS:

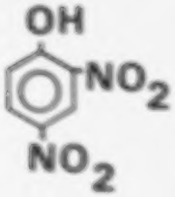
COMPOUND: 4,6-Dinitro-o-cresol



	● pH= 3.0			■ pH= 5.2			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	19.09			19.05			18.06		
2.5	16.95	2.14	856	17.65	1.40	560	16.52	1.54	616
5	15.90	3.19	638	16.78	2.27	454	15.66	2.40	480
10	14.36	4.73	473	14.52	4.53	453	13.68	4.38	438
20	9.79	9.30	465	12.24	6.81	340	10.12	7.94	397
25	9.77	9.32	373	10.70	8.35	334	10.08	7.98	319
50	3.39	15.70	314	5.42	13.63	273	6.63	11.43	229
75	1.10	17.99	248	2.85	16.20	216	4.99	13.07	174
100	0.43	18.66	187	1.18	17.87	179	4.10	13.96	140
125	0.23	18.86	151	0.62	18.43	147	3.16	14.90	119
150	0.14	18.95	126	0.32	18.73	125	2.36	15.70	105
200	0.05	19.04	95	0.20	18.85	94.2			

COMPOUND: 2,4-Dinitrophenol

STRUCTURE:



FORMULA: $C_6H_4N_2O_5$ **MOL. WT.** 184.11

FREUNDLICH PARAMETERS	pH		
	3.0	7.0	9.0
K	160	33	41
1/n	0.37	0.61	0.25
Corr. Coef. r	0.99	0.89	0.87
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	380	140	73
1.0	160	33	41
0.1	69	8.0	23
0.01	29	1.9	13

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_0, mg/l	0.1	0.01	0.001
1.0	110	500	2,100
0.1		45	200
0.01			18

GRANULAR CARBON COLUMN

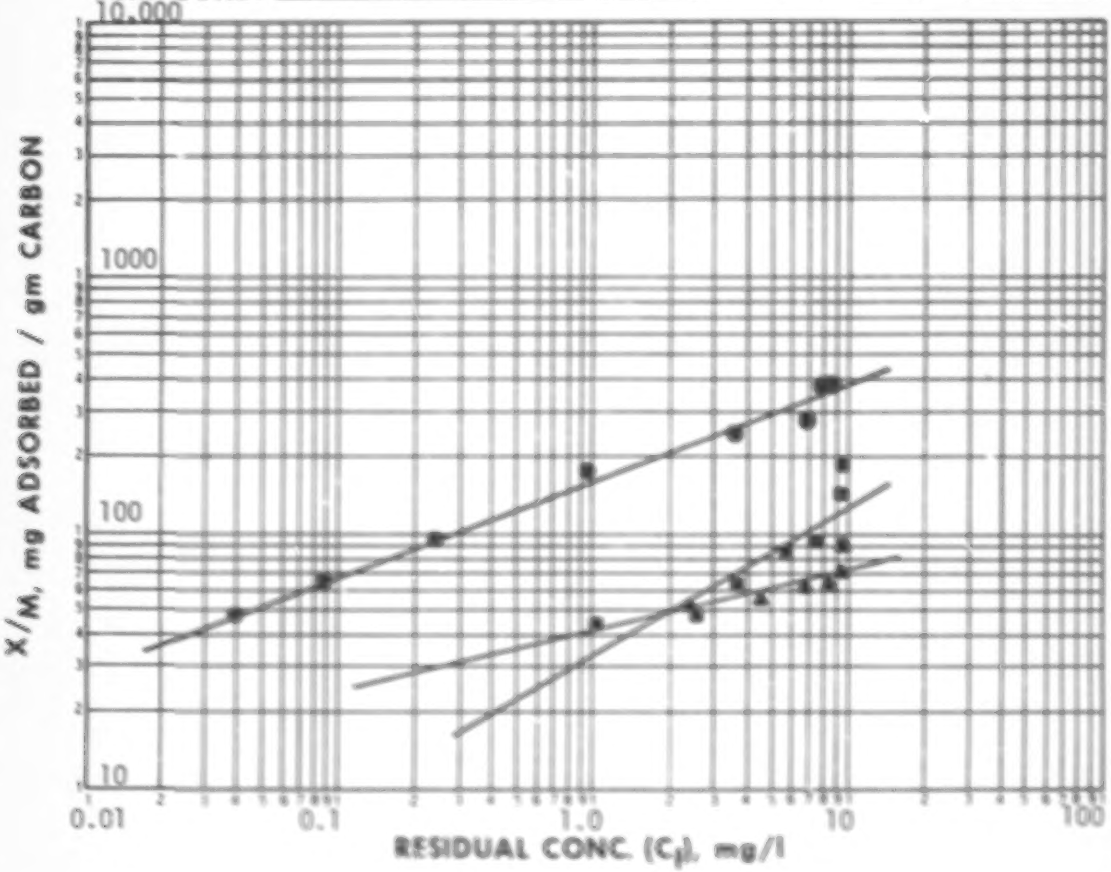
C_0, mg/l	
1.0	30
0.1	13
0.01	5.2

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 260 nm

REMARKS:

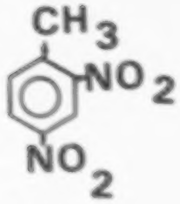
COMPOUND: 2,4-Dinitrophenol



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	9.88			9.95			9.97		
2.5	8.90	0.98	392	9.[illegible]	0.47	188			
5	7.95	1.93	386	9.19	0.76	152	9.52	0.45	90
10	7.02	2.86	286				9.27	0.70	70
25	3.66	6.22	248	7.63	2.32	93	8.39	1.58	63
50	0.98	8.90	178	5.83	4.12	82	6.93	3.04	61
100	0.24	9.64	96	3.69	6.26	63	4.49	5.48	55
150	0.09	9.79	65	2.69	7.26	48	2.30	7.67	51
200	0.04	9.84	49	1.06	8.89	44	1.14	8.83	44

COMPOUND: 2,4-Dinitrotoluene

STRUCTURE:



FORMULA: $C_7H_6N_2O_4$ **MOL. WT.** 182.14

FREUNDLICH PARAMETERS	pH		
	5.4		
K	146		
1/n	0.31		
Corr. Coef. r	0.94		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	146		
0.1	71		
0.01	34		
0.01	17		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	13	29	59
0.1		2.6	5.9
0.01			0.5

GRANULAR CARBON COLUMN

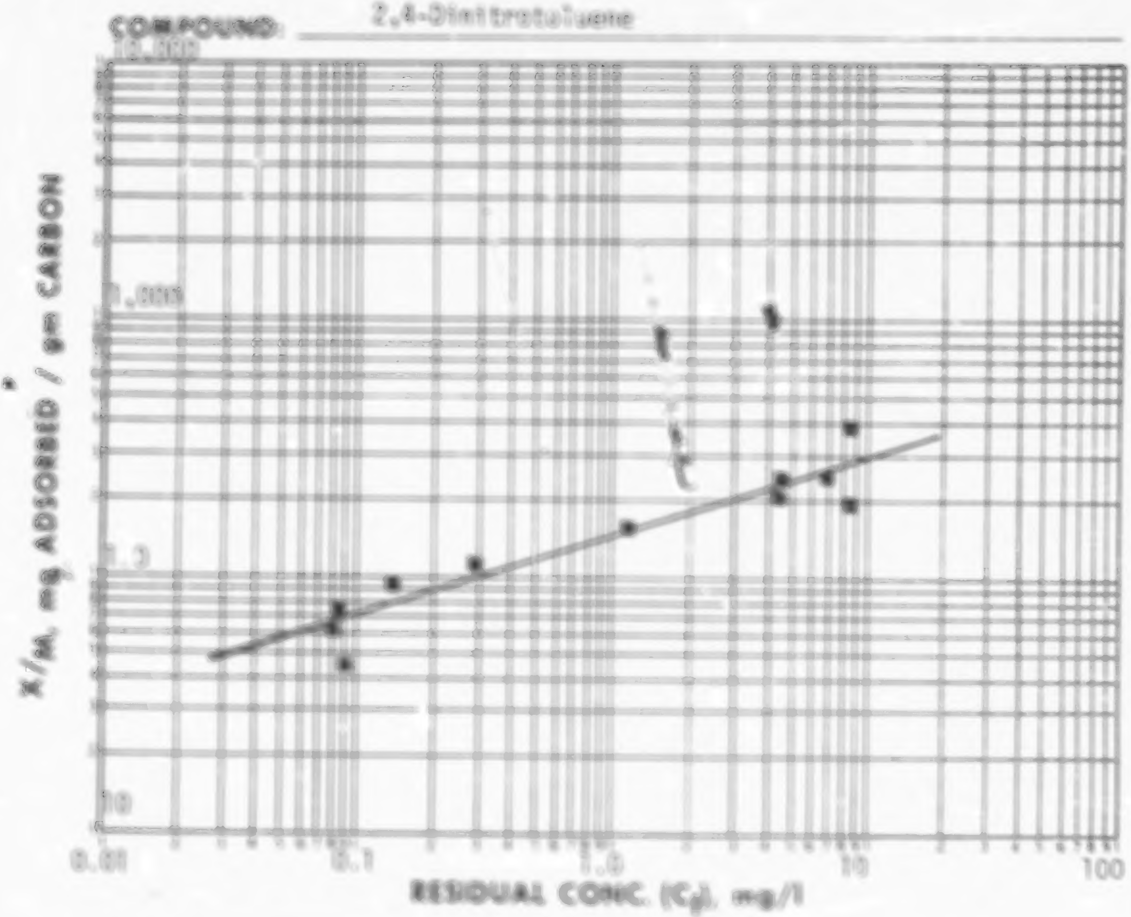
C_o, mg/l	
1.0	6.9
0.1	1.4
0.01	0.3

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 252 nm.

REMARKS:

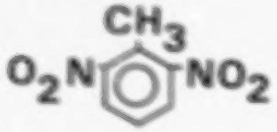
COMPOUND: 2,4-Dinitrotoluene



	■ pH= 5.4			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	9.46								
2.5	8.46	1.00	400						
5	8.48	0.980	196						
10	6.92	2.54	254						
20	4.42	5.04	252						
25	4.31	5.15	206						
50	1.16	8.30	166						
75	0.290	9.17	122						
100	0.140	9.32	93						
125	0.086	9.38	75						
150	0.080	9.38	63						
200	0.090	9.37	47						

COMPOUND: 2,6-Dinitrotoluene

STRUCTURE:



FORMULA: $C_7H_6N_2O_4$ **MOL. WT.** 182.14

FREUNDLICH PARAMETERS	pH		
	5.4		
K	145		
1/n	0.32		
Corr. Coef. r	0.98		
INITIAL CONC. mg/l	**ADSORPTION CAPACITY, mg/gm**		
1.0	145		
0.1	70		
0.01	33		
0.001	16		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON • GRANULAR CARBON COLUMN

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	13	30	62
0.1		2.7	6.2
0.01			0.6

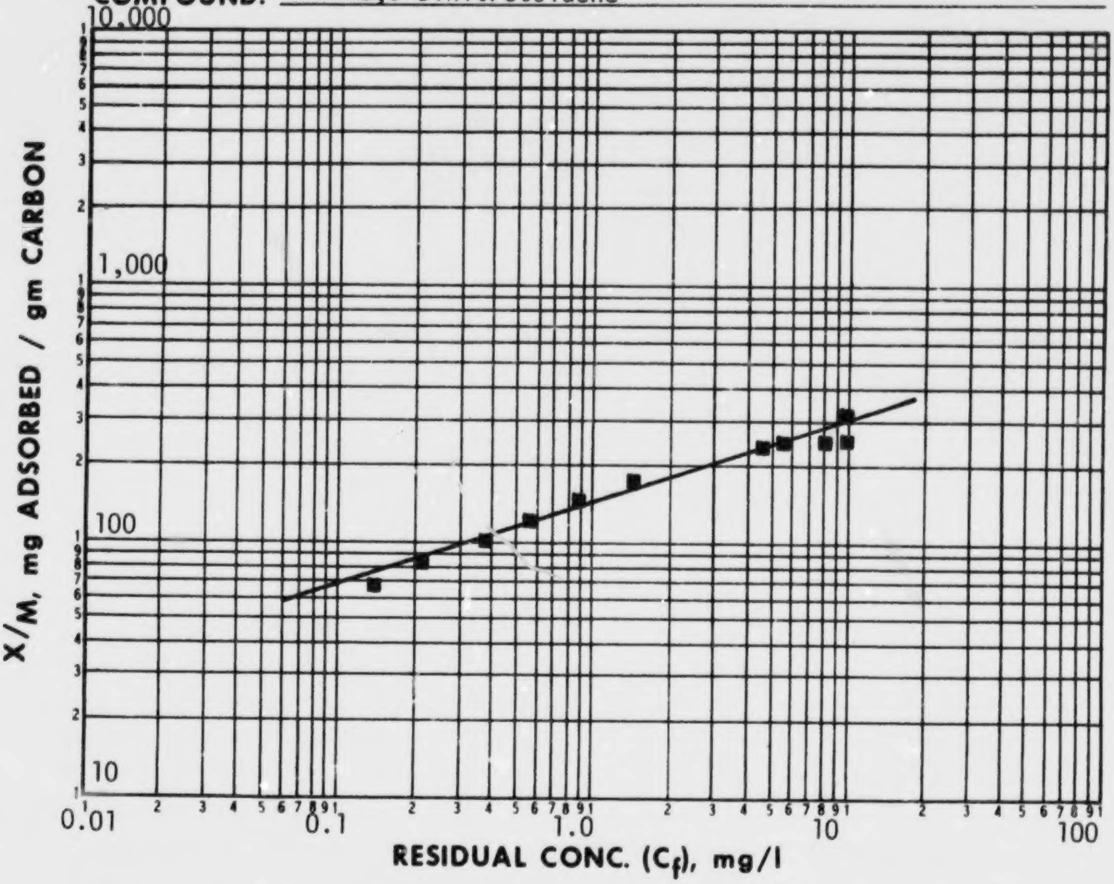
C_o, mg/l	
1.0	6.9
0.1	1.4
0.01	0.3

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 242 nm.

REMARKS:

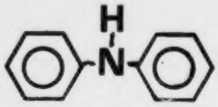
COMPOUND: 2,6-Dinitrotoluene



	■ pH= 5.4			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	10.58								
2.5	9.80	0.780	312						
5	9.28	1.30	260						
10	8.00	2.58	258						
20	5.48	5.10	255						
25	4.50	6.08	243						
50	1.45	9.13	183						
60	0.89	9.69	162						
75	0.56	10.02	134						
100	0.38	10.20	102						
125	0.21	10.37	83						
150	0.14	10.44	70						

COMPOUND: Diphenylamine

STRUCTURE:



FORMULA: $C_{12}H_{11}N$ **MOL. WT.** 169.24

FREUNDLICH PARAMETERS	pH		
	All data pooled		
K	120		
1/n	0.31		
Corr. Coef. r	0.98		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	240		
1.0	120		
0.1	57		
0.01	28		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	16	35	72
0.1		3.2	7.2
0.01			0.65

GRANULAR CARBON COLUMN

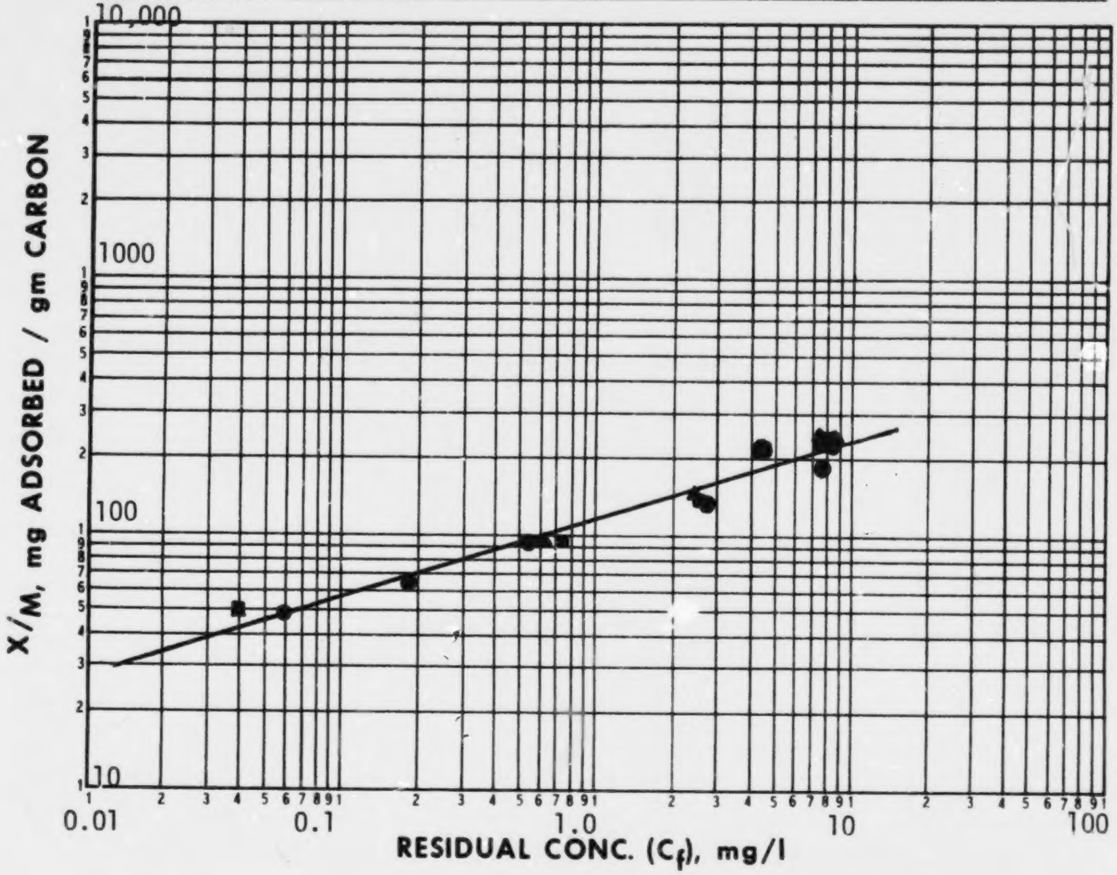
C_o, mg/l	
1.0	8.5
0.1	1.8
0.01	0.4

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 279 nm

REMARKS:

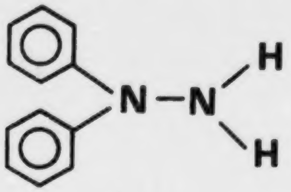
COMPOUND: Diphenylamine



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	9.80			10.00			9.88		
5	8.64	1.16	232	8.80	1.20	240	8.70	1.18	236
10	7.88	1.92	192	7.73	2.27	227	7.42	2.46	246
25	4.38	5.42	217	4.45	5.55	222	4.37	5.51	220
50	2.82	6.98	140	2.65	7.35	147	2.51	7.37	147
100	0.55	9.25	93	0.73	9.27	93	0.62	9.26	93
150	0.19	9.61	64	0.19	9.81	65	0.19	9.69	65
200	0.06	9.74	49	0.04	9.96	50	0.04	9.84	49

COMPOUND: 1,1-Diphenylhydrazine

STRUCTURE:



FORMULA: $C_{12}H_{12}N_2$ **MOL. WT.** 184.24

FREUNDLICH PARAMETERS	pH		
	7.5		
K	135		
1/n	0.16		
Corr. Coef. r	0.75		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	194		
1.0	135		
0.1	94		
0.01	65		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	10	15	22
0.1		1.4	2.2
0.01			0.2

GRANULAR CARBON COLUMN

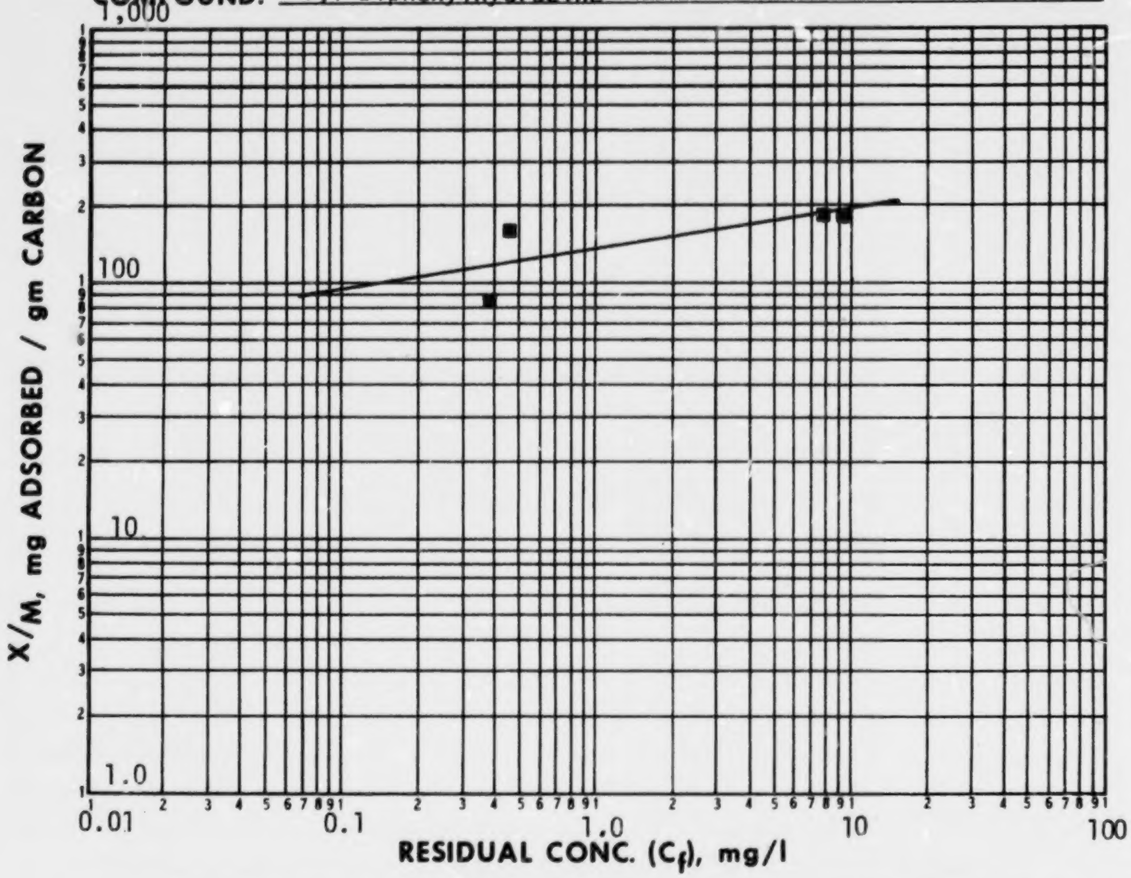
C_o, mg/l	
1.0	7.4
0.1	1.1
0.01	0.2

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 230 nm

REMARKS:

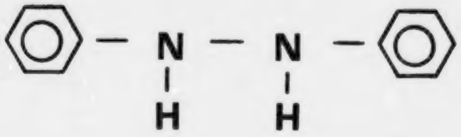
COMPOUND: 1,1-Diphenylhydrazine



	■ pH= 7.5			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	9.95								
4.6	9.07	0.88	191						
4.6	9.09	0.86	187						
11.2	7.83	2.12	190						
56.1	0.46	9.49	167						
112	0.39	9.56	85						

COMPOUND: 1,2-Diphenylhydrazine

STRUCTURE:



FORMULA: $C_{12}H_{12}N_2$ **MOL. WT.** 184.24

FREUNDLICH PARAMETERS	pH		
	5.3		
K	16,000		
1/n	2.0		
Corr. Coef. r	0.95		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1	16,000		
0.1	160		
0.01	1.5		
0.001	0.015		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	5.7	630	63,000
0.1		57	6,200
0.01			570

GRANULAR CARBON COLUMN

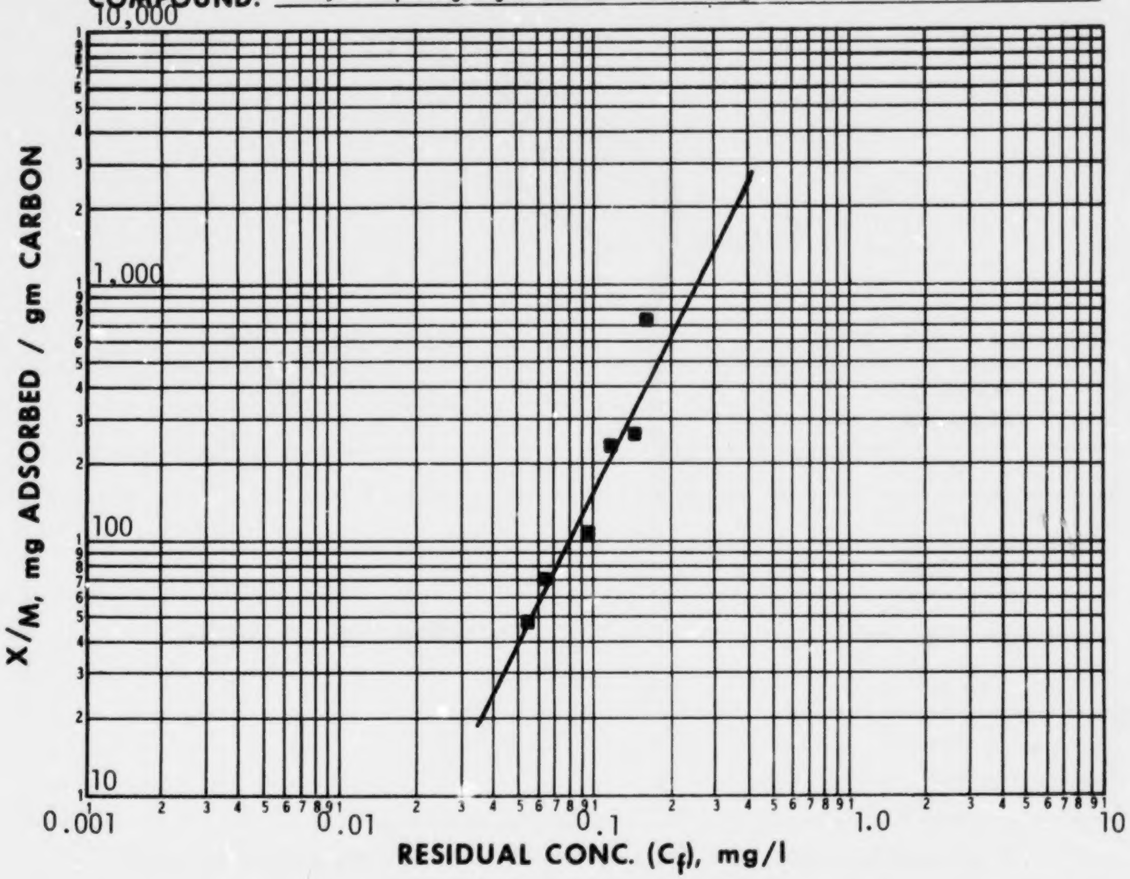
C_o, mg/l	
1.0	0.06
0.1	0.64
0.01	6.7

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Total Organic Carbon

REMARKS: Rapid oxidation to azobenzene; azobenzene solubility is 0.25 mg/l.

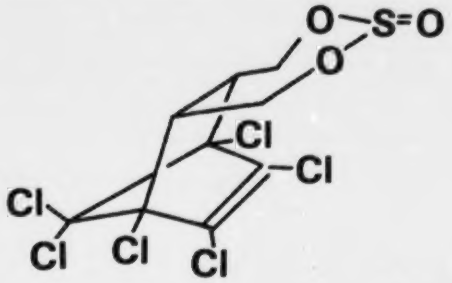
COMPOUND: 1,2-Diphenylhydrazine



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	0.238								
0.1	0.167	0.071	710						
0.3	0.158	0.080	267						
0.5	0.123	0.115	230						
1.3	0.0958	0.142	109						
2.5	0.0640	0.174	70						
3.8	0.0541	0.184	48						

COMPOUND: α-Endosulfan

STRUCTURE:



FORMULA: $C_9H_6Cl_6SO_3$ **MOL. WT.** 406.93

FREUNDLICH PARAMETERS	pH		
	5.3		
K	194		
1/n	0.50		
Corr. Coef. r	0.98		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	194		
0.1	61		
0.01	19		
0.001	6.1		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	15	50	160
0.1		4.6	16
0.01			1.4

GRANULAR CARBON COLUMN

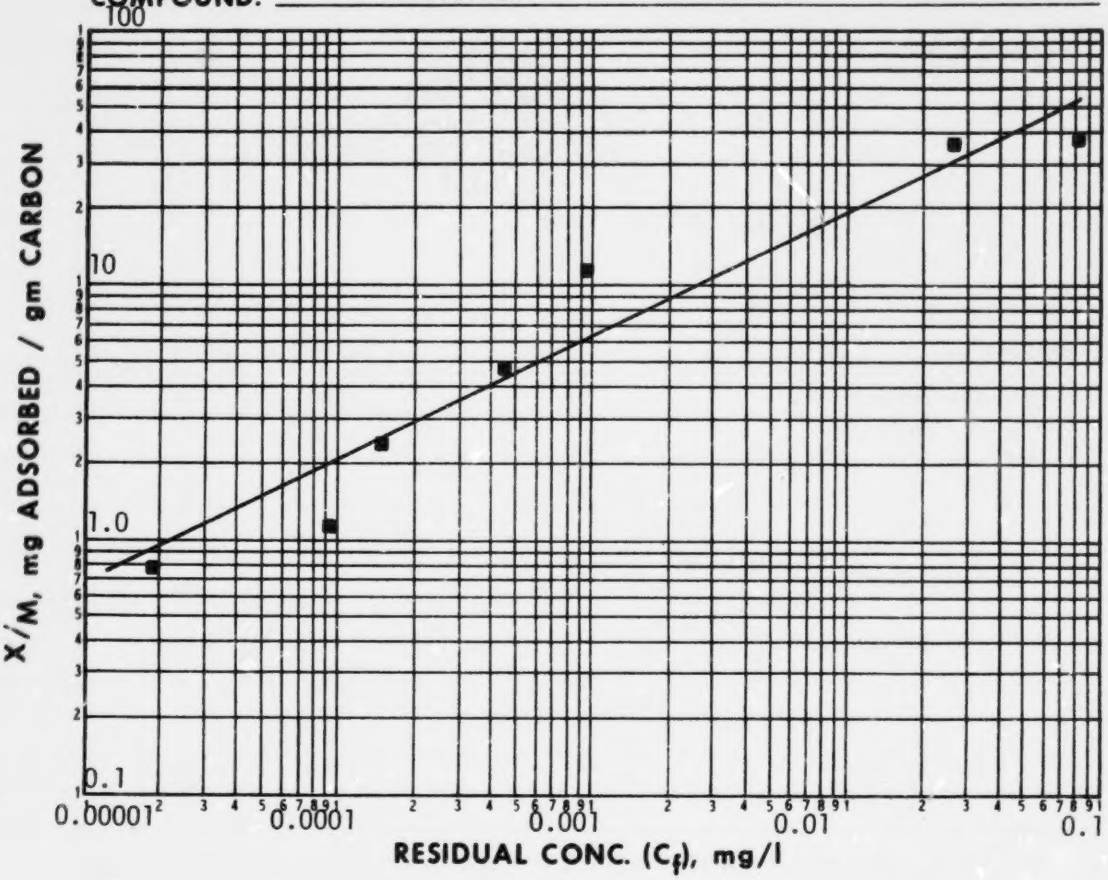
C_o, mg/l	
1.0	5.2
0.1	1.6
0.01	0.5

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent extraction - G.C.

REMARKS: Data were obtained on a mixture containing 62% alpha and 38% beta isomers.

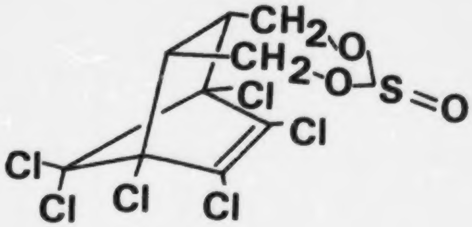
COMPOUND: α-Endosulfan



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	0.119								
1.0	0.081	0.038	38.0						
2.5	0.026	0.093	37.2						
10	0.001	0.118	11.8						
25	0.0005	0.118	4.74						
50	0.0002	0.119	2.38						
100	0.0001	0.119	1.19						
150	0.00002	0.119	0.79						
200	0.000008	0.119	0.59						

COMPOUND: β-Endosulfan

STRUCTURE:



FORMULA: $C_9H_6Cl_6SO_3$ **MOL. WT.** 406.93

FREUNDLICH PARAMETERS	pH		
	5.3		
K	615		
1/n	0.83		
Corr. Coef. r	0.98		
INITIAL CONC. mg/l	**ADSORPTION CAPACITY, mg/gm**		
1.0	615		
0.1	92		
0.01	14		
0.001	2.0		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	10	74	500
0.1		6.7	50
0.01			4.5

GRANULAR CARBON COLUMN

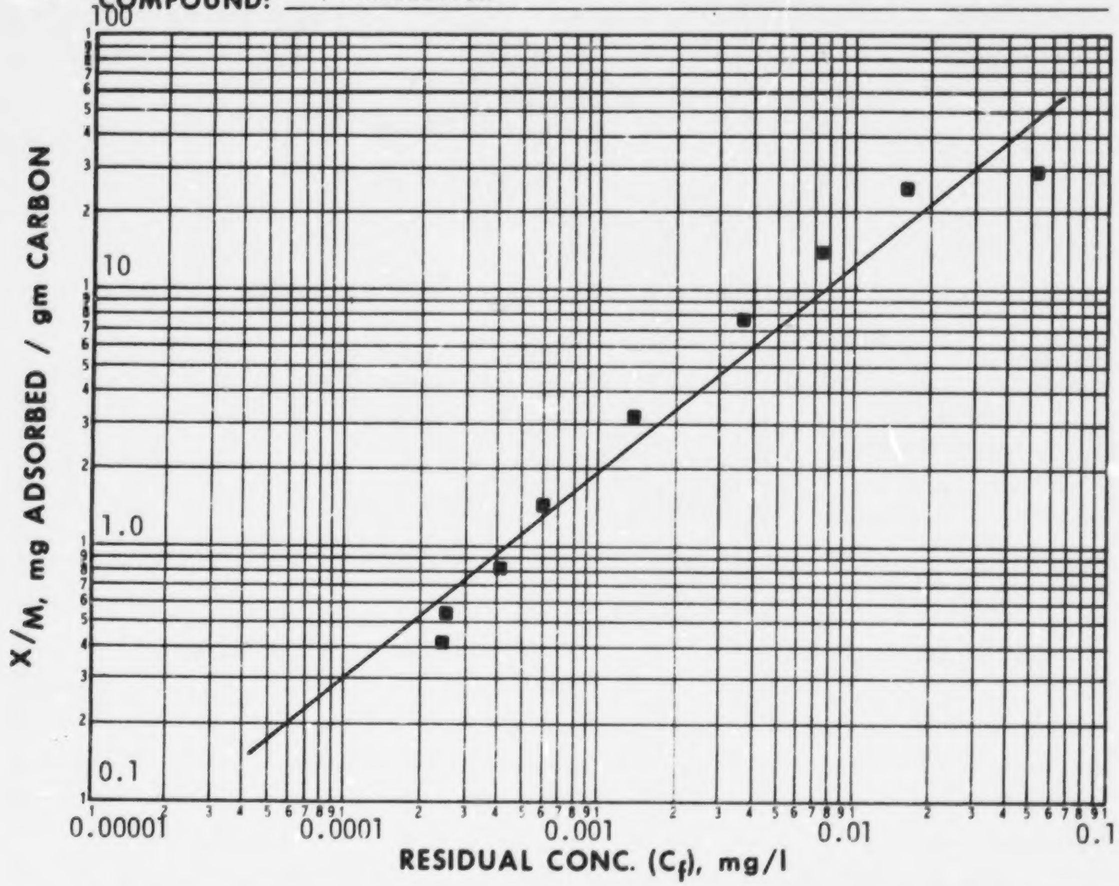
C_o, mg/l	
1.0	1.6
0.1	1.1
0.01	0.7

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent extraction - G.C.

REMARKS: Data were obtained on a mixture containing 62% alpha and 38% beta isomers.

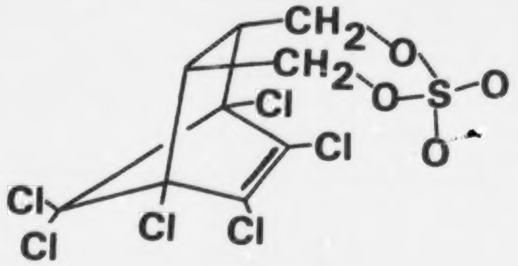
COMPOUND: β-Endosulfan



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	0.082								
1.0	0.052	0.030	30.0						
2.5	0.017	0.065	26.0						
5	0.008	0.074	14.8						
10	0.004	0.078	7.80						
25	0.001	0.081	3.24						
50	0.0006	0.081	1.62						
100	0.0004	0.082	0.82						
150	0.0003	0.082	0.54						
200	0.0002	0.082	0.41						

COMPOUND: Endosulfan sulfate

STRUCTURE:



FORMULA: $C_9H_6Cl_6SO_4$ **MOL. WT.** 422.93

FREUNDLICH PARAMETERS	pH		
	5.3		
K	686		
1/n	0.81		
Corr. Coef. r	0.99		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	686		
0.1	105		
0.01	16		
0.001	2.5		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	8.5	60	390
0.1		5.5	39
0.01			3.5

GRANULAR CARBON COLUMN

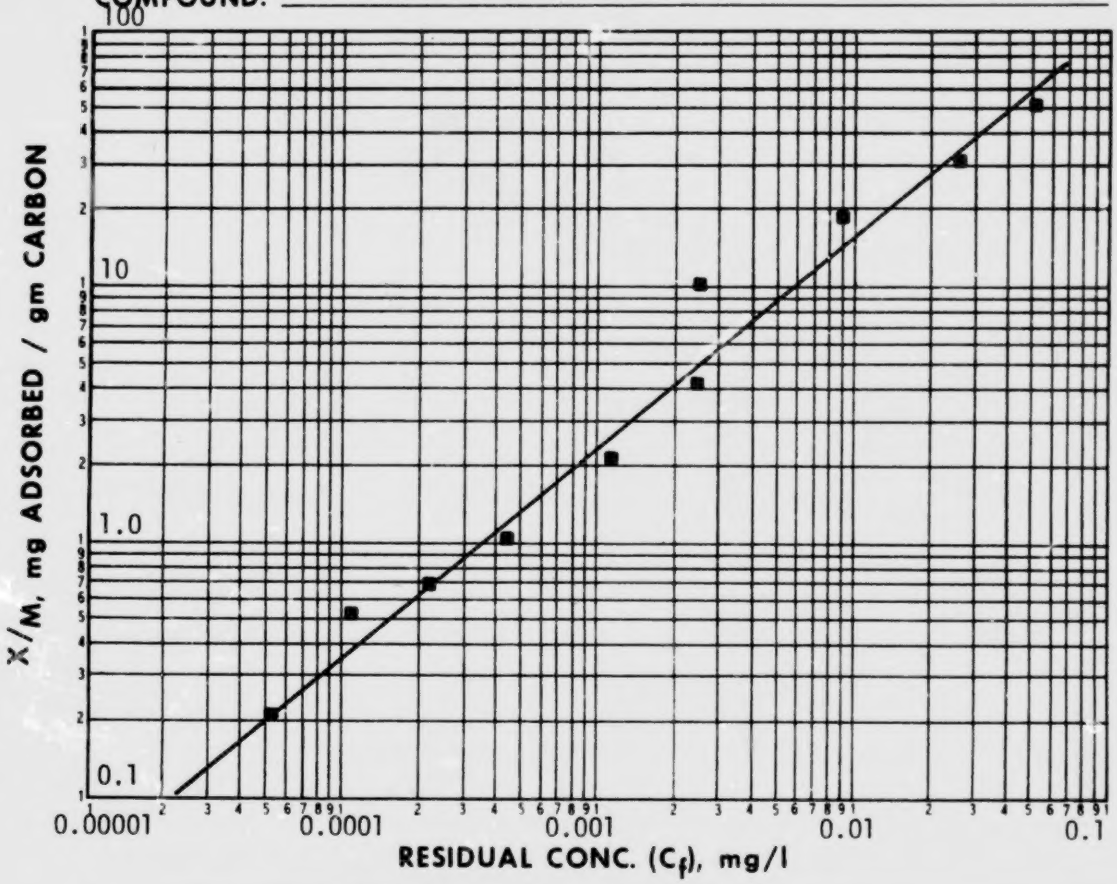
C_o, mg/l	
1.0	1.5
0.1	1.0
0.01	0.6

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent extraction - G.C.

REMARKS:

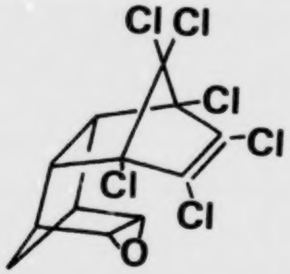
COMPOUND: Endosulfan sulfate



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	0.105								
1.0	0.054	0.051	51.0						
2.5	0.027	0.078	31.2						
5	0.0090	0.096	19.2						
10	0.0026	0.102	10.2						
25	0.0023	0.103	4.10						
50	0.0012	0.104	2.07						
100	0.0004	0.105	1.05						
150	0.0002	0.105	0.70						
200	0.0001	0.105	0.52						
500	0.00005	0.105	0.21						
1000	0.00003	0.105	0.10						

COMPOUND: Endrin

STRUCTURE:



FORMULA: $C_{12}H_8Cl_6O$ **MOL. WT.** 381.0

FREUNDLICH PARAMETERS	pH		
	5.3		
K	666		
1/n	0.80		
Corr. Coef. r	0.95		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	666		
0.1	106		
0.01	17		
0.001	2.7		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	8.5	60	380
0.1		5.4	37
0.01			3.4

GRANULAR CARBON COLUMN

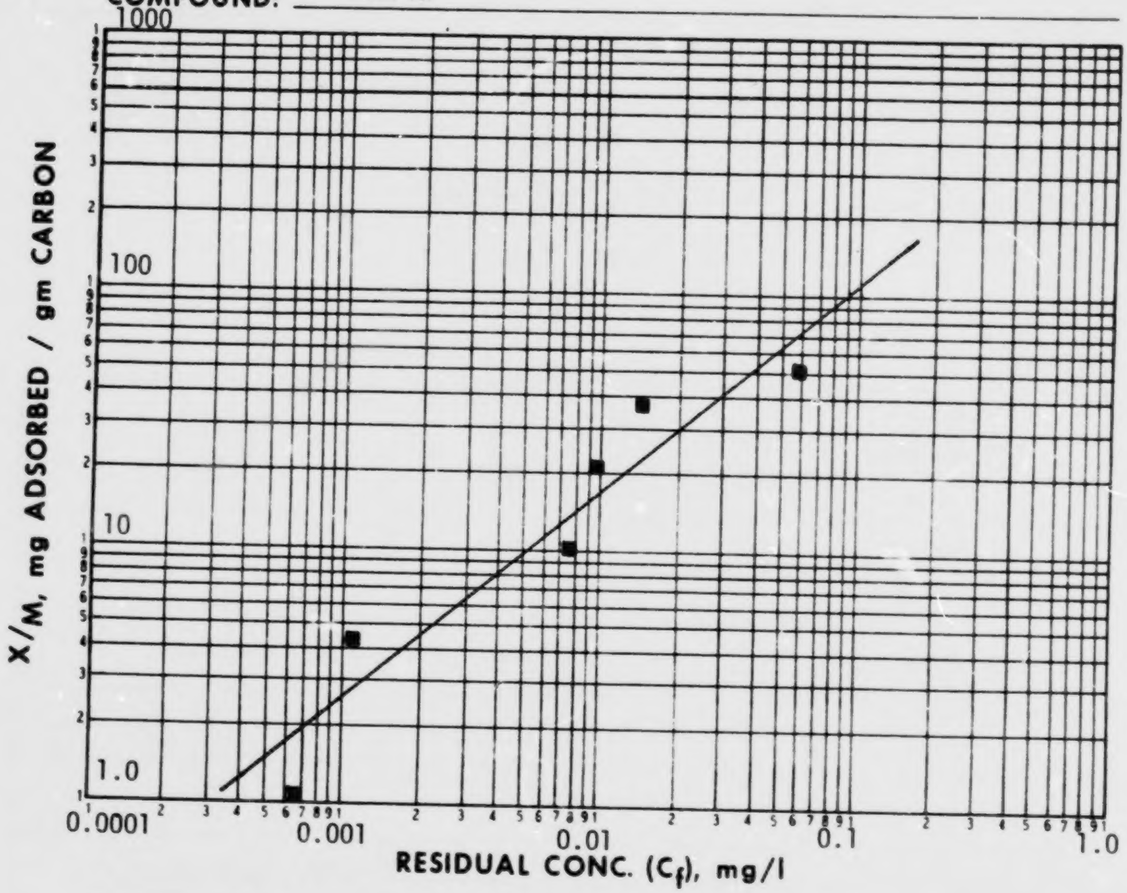
C_o, mg/l	
1.0	1.5
0.1	0.9
0.01	0.6

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent extraction - G.C.

REMARKS:

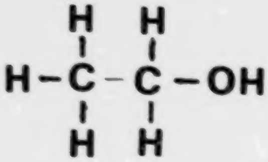
COMPOUND: Endrin



	● pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	0.110								
1.0	0.059	0.051	51.0						
2.5	0.015	0.095	38.0						
5	0.010	0.100	20.0						
10	0.008	0.102	10.2						
25	0.001	0.109	4.36						
100	0.0006	0.109	1.09						

COMPOUND: Ethanol

STRUCTURE:



$$\begin{array}{ccccccc} & & H & & H & & \\ & & | & & | & & \\ H & - & C & - & C & - & OH \\ & & | & & | & & \\ & & H & & H & & \end{array}$$

FORMULA: C_2H_6O **MOL. WT.** 46.07

FREUNDLICH PARAMETERS	pH		
	5.3		
K			
1/n			
Corr. Coef. r			
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l			

GRANULAR CARBON COLUMN

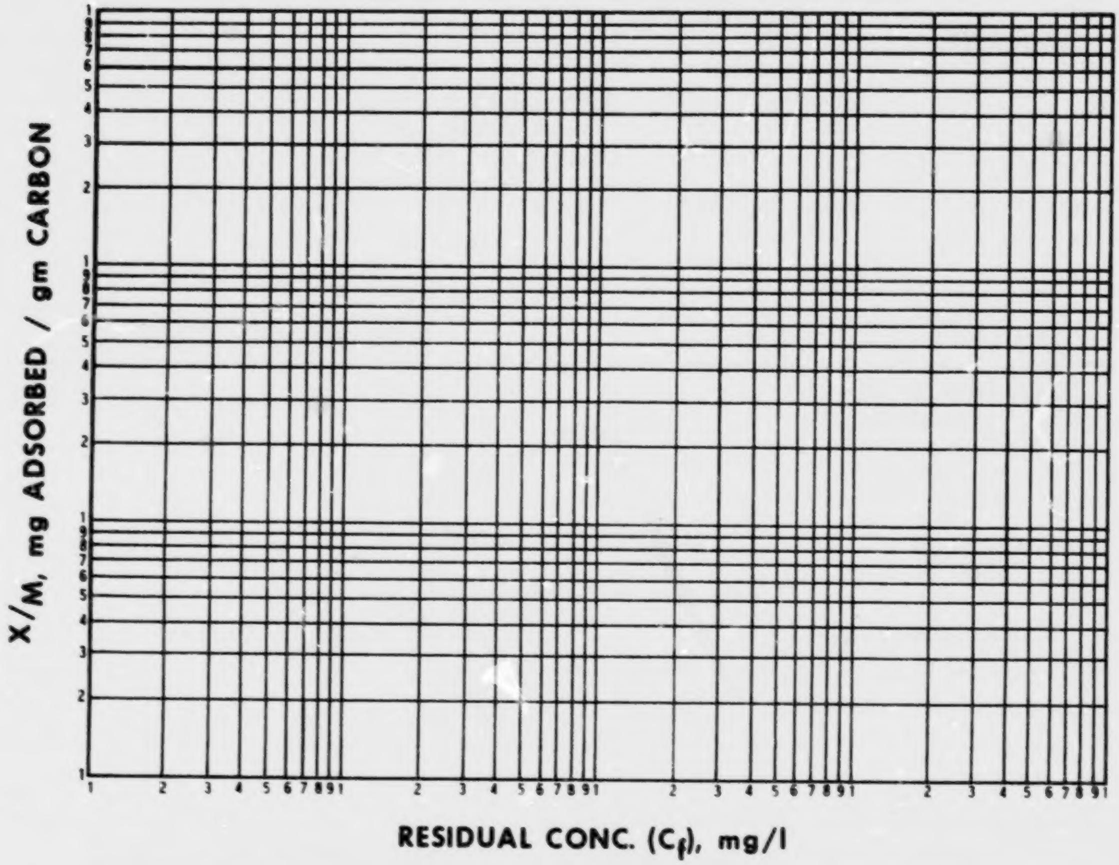
C_o, mg/l	

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Total Organic Carbon

REMARKS: Not adsorbed

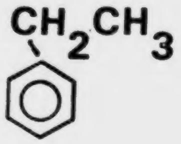
COMPOUND: Ethanol



	pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	66.8								
190	63.9	2.90	15.2						
480	62.7	4.10	8.54						
954	63.1	3.70	3.88						
1520	65.4	1.40	0.92						
4800	62.7	4.10	0.85						
9600	62.4	4.40	0.46						

COMPOUND: Ethylbenzene

STRUCTURE:



FORMULA: C_8H_{10} **MOL. WT.** 106.16

FREUNDLICH PARAMETERS	pH		
	7.4		
K	53		
1/n	0.79		
Corr. Coef. r	0.96		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	325		
1.0	53		
0.1	8.5		
0.01	1.4		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON
C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	110	710	4,400
0.1		65	440
0.01			40

GRANULAR CARBON COLUMN

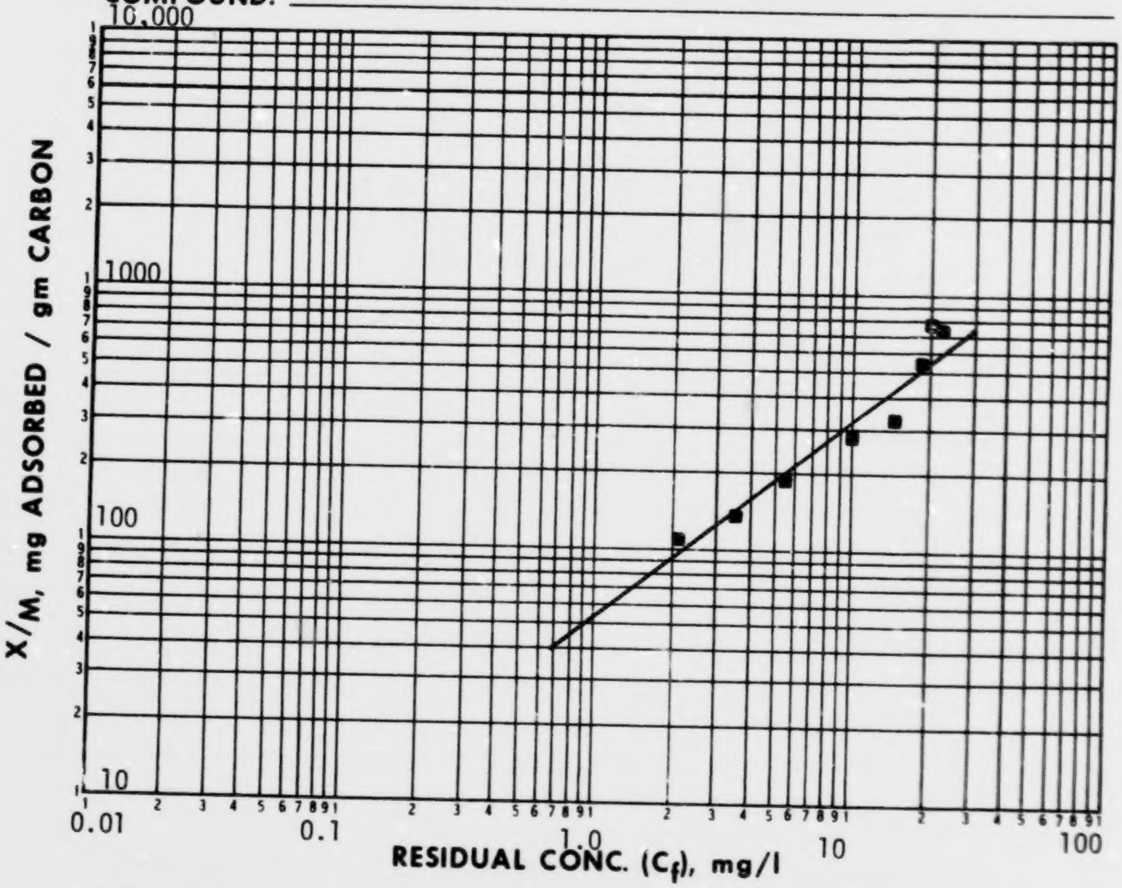
C_o, mg/l	
1.0	19
0.1	12
0.01	7.2

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 260 nm

REMARKS:

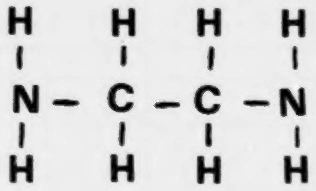
COMPOUND: Ethylbenzene



	■ pH= 7.3			pH=			pH=		
CARBON DOSE mg/l	**C_f**	**$C_o - C_f = X$**	**X/M**	**C_f**	**$C_o - C_f = X$**	**X/M**	**C_f**	**$C_o - C_f = X$**	**X/M**
0	24.3								
2.5	22.5	1.80	720						
5	20.4	3.90	780						
10	18.9	5.40	540						
25	16.2	8.10	324						
50	10.2	14.10	282						
100	5.4	18.90	189						
150	3.6	20.70	138						
200	2.1	22.20	111						

COMPOUND: Ethylenediamine

STRUCTURE:



$H_2N-CH_2-CH_2-NH_2$

FORMULA: $C_2H_8N_2$ **MOL. WT.** 60.10

FREUNDLICH PARAMETERS	**pH**		
K			
1/n			
Corr. Coef. r			
INITIAL CONC. mg/l	**ADSORPTION CAPACITY, mg/gm**		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON
C_f, mg/l

C_o, mg/l			

GRANULAR CARBON COLUMN

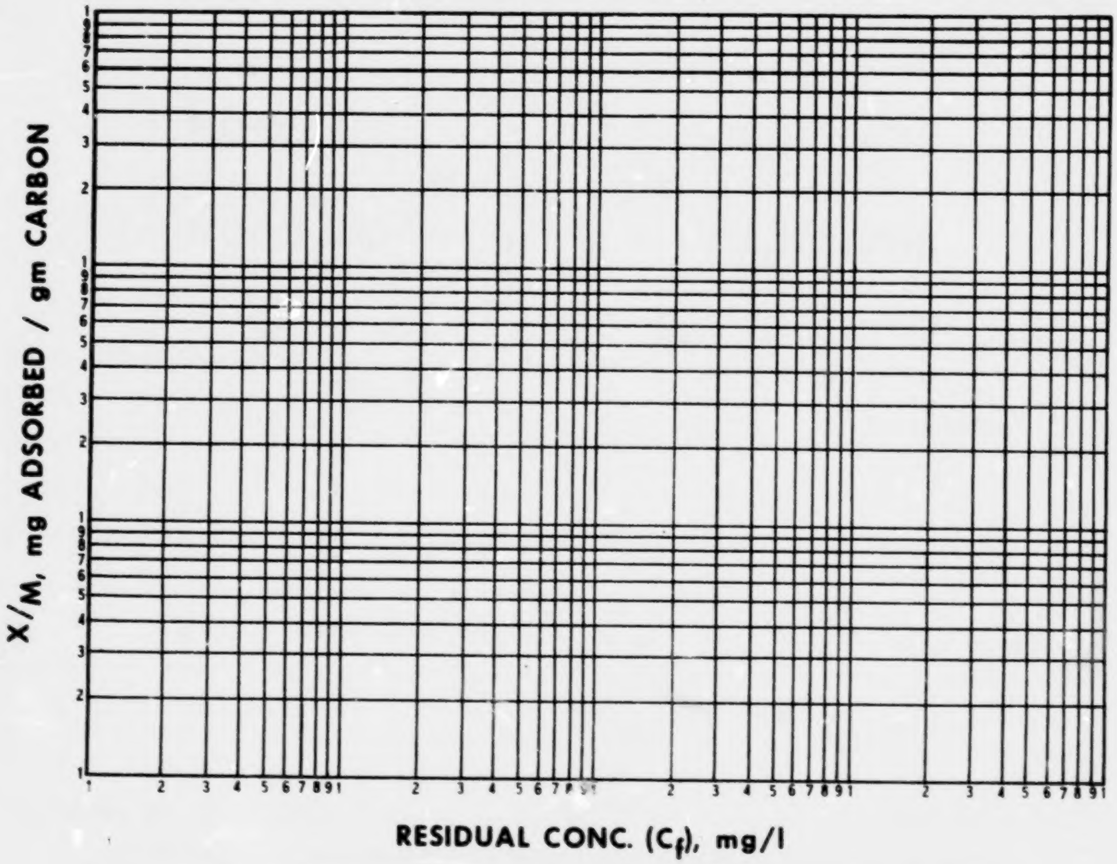
C_o, mg/l	

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Total Organic Carbon

REMARKS: Not adsorbed

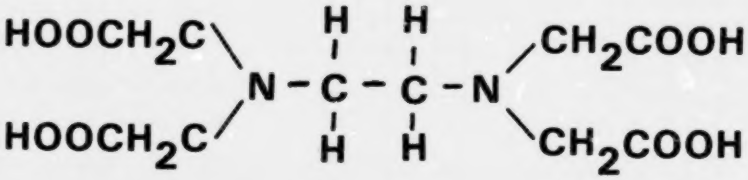
COMPOUND: Ethylenediamine



	pH=			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	26.5			25.5			24.5		
5	25.0			24.5			23.5		
10	24.5			25.5			23.5		
25	24.5			25.0			23.0		
50	24.0			24.5			25.0		
100	25.0			23.0			22.0		
150	23.5			24.0			25.5		
200	24.0			22.0			26.0		

COMPOUND: Ethylenediaminetetraaceticacid (EDTA)

STRUCTURE:



FORMULA: $C_{10}H_{16}N_2O_8$ **MOL. WT.** 292.3

FREUNDLICH PARAMETERS	pH		
	All data pooled		
K	0.86		
1/n	1.5		
Corr. Coef. r	0.92		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	30		
1.0	0.86		
0.1	0.25		
0.01	0.0007		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	36,000	>100,000	>100,000
0.1		>100,000	>100,000
0.01			>100,000

GRANULAR CARBON COLUMN

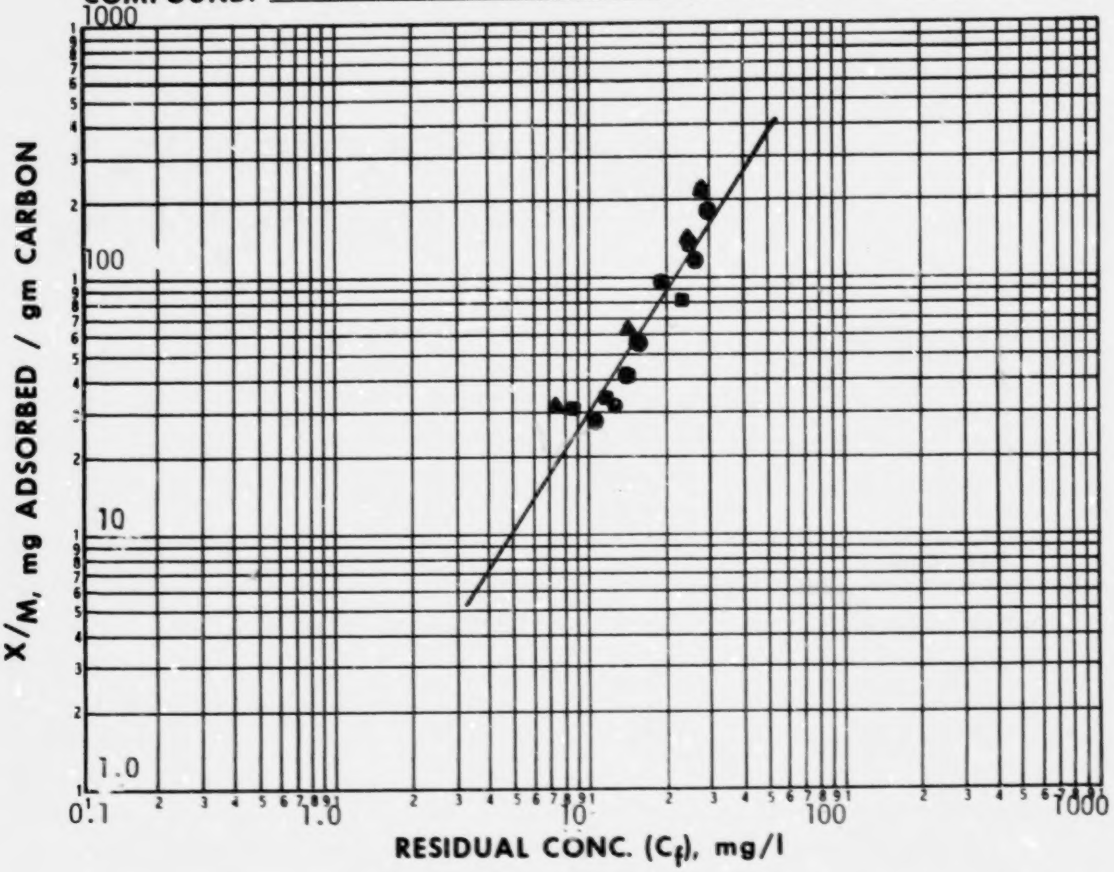
C_o, mg/l	
1.0	1,160
0.1	3,970
0.01	13,600

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Total Organic Carbon

REMARKS:

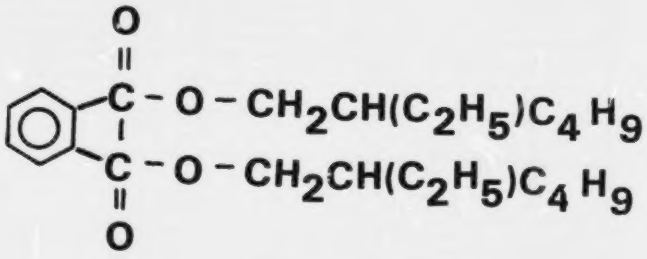
COMPOUND: Ethylenediaminetetraaceticacid (EDTA)



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	39.2			39.2			39.2		
50	30.0	9.2	184				28.2	11.0	220
100	26.8	12.4	124	25.1	14.1	141	24.3	14.9	149
200	19.5	19.7	98.5	23.1	16.1	80.5			
400	17.0	22.2	55.5	17.0	22.2	55.5	14.6	24.6	61.5
600	14.6	24.6	41.0	15.1	24.1	40.2			
800	13.4	25.8	32.3	11.7	27.5	34.4			
1000	11.4	27.8	27.8	8.8	30.4	30.4	7.30	31.8	31.9

COMPOUND: bis(2-Ethylhexyl) phthlate

STRUCTURE:



FORMULA: $C_{24}H_{38}O_4$ **MOL. WT.** 390.56

FREUNDLICH PARAMETERS	pH		
	5.3		
K	11,300		
1/n	1.5		
Corr. Coef. r	0.91		
INITIAL CONC. mg/l	**ADSORPTION CAPACITY, mg/gm**		
1.0	11,300		
0.1	340		
0.01	10		
0.001	0.32		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	2.5	88	2,800
0.1		8.0	280
0.01			25

GRANULAR CARBON COLUMN

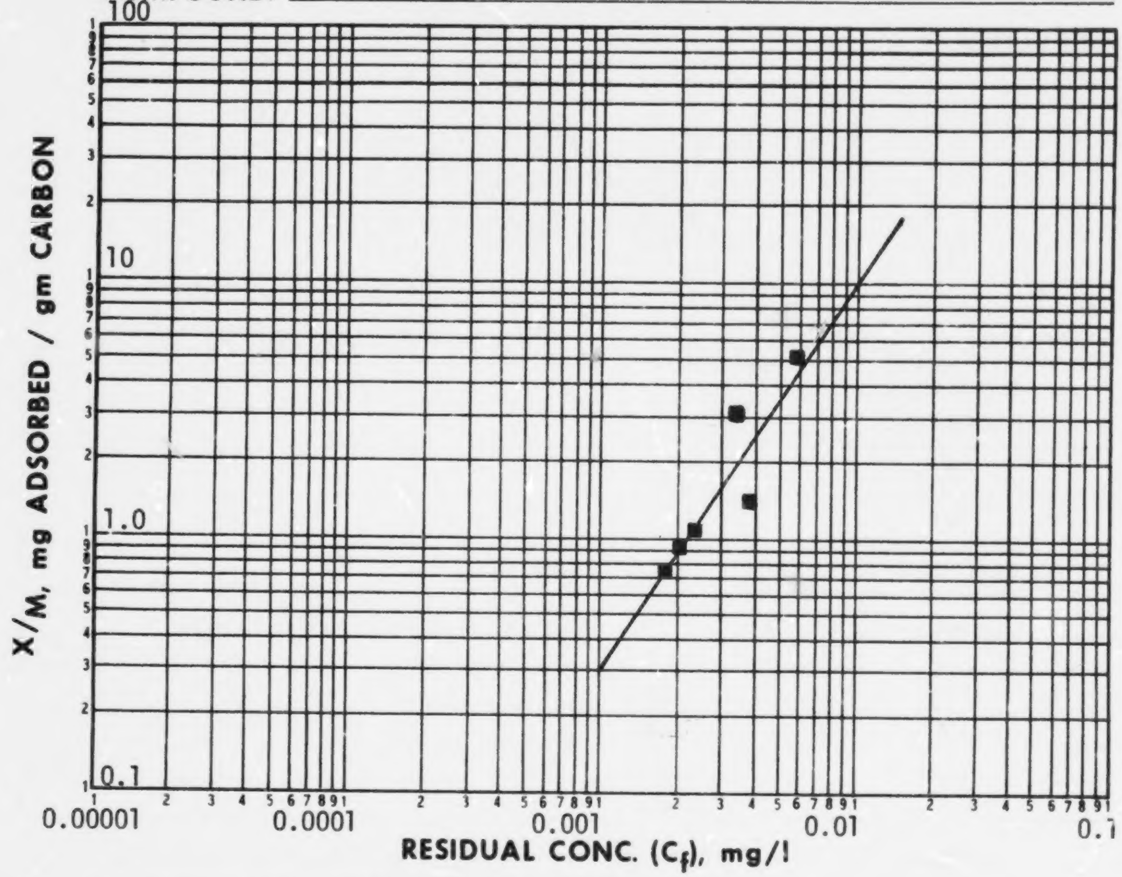
C_o, mg/l	
1.0	0.1
0.1	0.3
0.01	1.0

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent Extraction - G.C.

REMARKS:

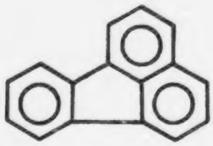
COMPOUND: bis (2-Ethylhexyl) phthlate



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f*	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	11.03								
1.0	5.94	5.09	5.09						
2.5	3.28	7.75	3.10						
5	3.80	7.23	1.45						
7.5	2.29	8.74	1.17						
10	2.00	9.03	0.903						
12.5	1.83	9.20	0.736						
* x 10^3									

COMPOUND: Fluoranthene

STRUCTURE:



FORMULA: $C_{16}H_{10}$ **MOL. WT.** 202.26

FREUNDLICH PARAMETERS	pH		
	5.3		
K	664		
1/n	0.61		
Corr. Coef. r	0.88		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	664		
0.1	164		
0.01	41		
0.001	10		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	6.0	24	100
0.1		2.2	9.9
0.01			0.9

GRANULAR CARBON COLUMN

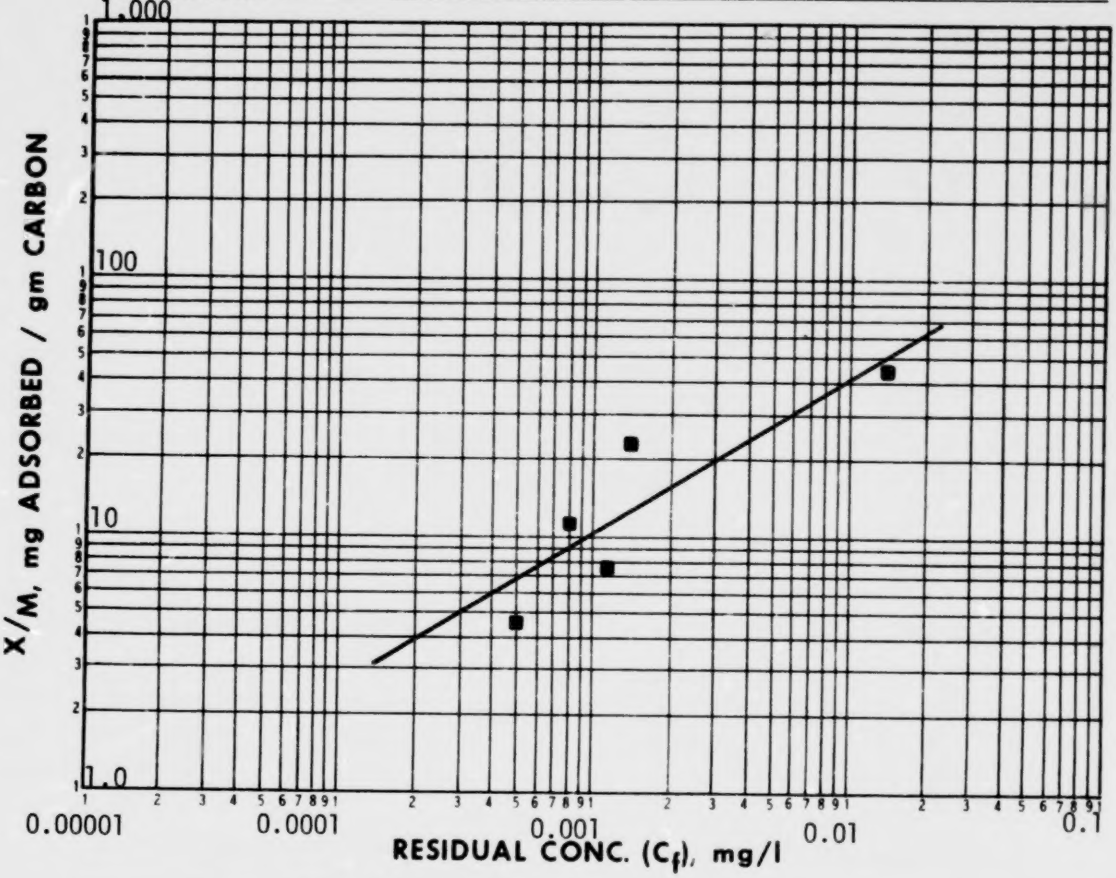
C_o, mg/l	
1.0	1.5
0.1	0.6
0.01	0.2

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent Extraction - G.C.

REMARKS:

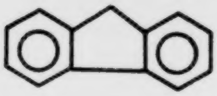
COMPOUND: Fluoranthene



	● pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	0.0581								
1.0	0.0140	0.0441	44.1						
2.5	0.0014	0.0567	22.7						
5	0.0008	0.0573	11.5						
7.5	0.0012	0.0569	7.6						
12.5	0.0005	0.0576	4.6						

COMPOUND: Fluorene

STRUCTURE:



FORMULA: $C_{13}H_{10}$ **MOL. WT.** 166.22

FREUNDLICH PARAMETERS	pH		
	5.3		
K	330		
1/n	0.28		
Corr. Coef. r	0.94		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	330		
0.1	170		
0.01	89		
0.001	46		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	5.3	11	22
0.1		1.0	2.1
0.01			0.2

GRANULAR CARBON COLUMN

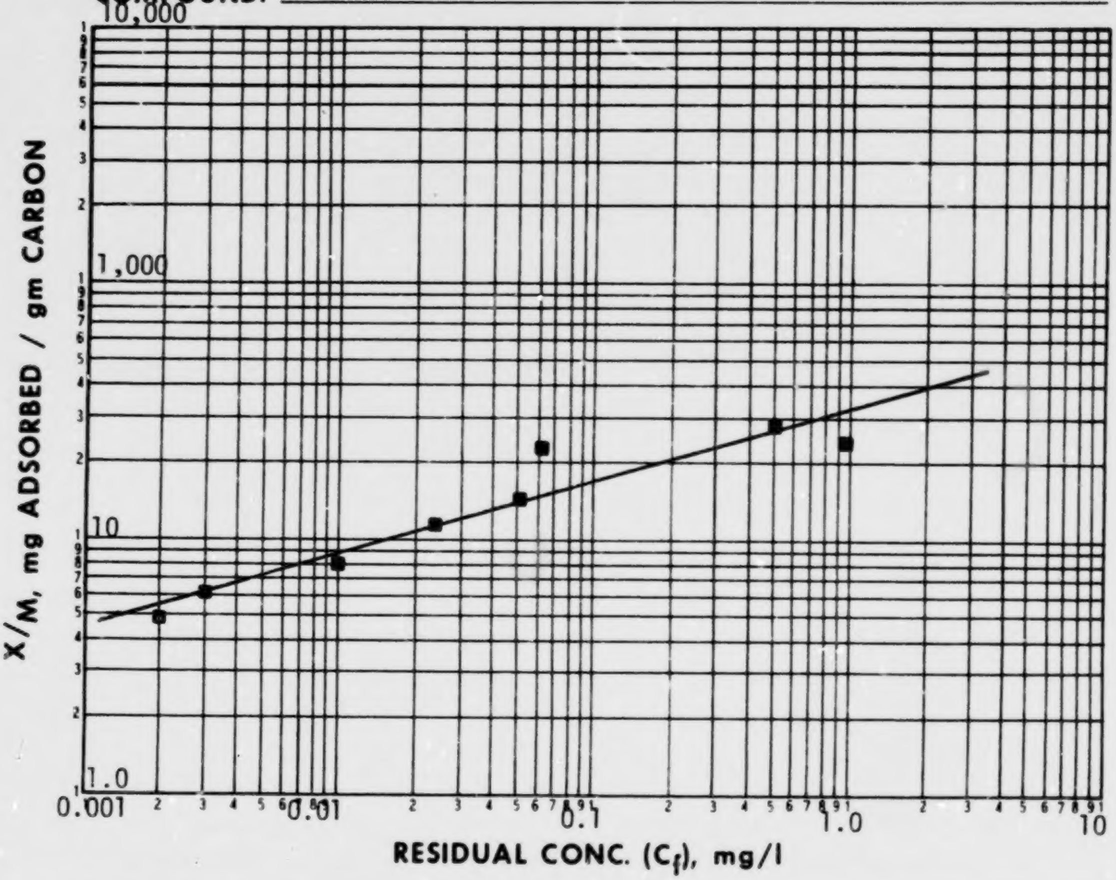
C_o, mg/l	
1.0	3.0
0.1	0.6
0.01	0.1

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent Extraction - G.C.

REMARKS:

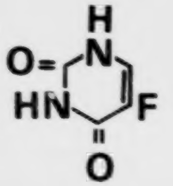
COMPOUND: Fluorene



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	1.21								
1	0.972	0.238	238						
2.5	0.501	0.709	284						
5	0.061	1.149	230						
7.5	0.051	1.159	155						
10	0.023	1.187	119						
15	0.010	1.200	80.0						
20	0.003	1.207	60.4						
25	0.002	1.208	48.3						

COMPOUND: 5-Fluorouracil

STRUCTURE:



FORMULA: $C_4H_3N_2O_2F$ **MOL. WT.** 130.08

FREUNDLICH PARAMETERS	pH		
	pH 3 and 7 pooled	9.0	
K	5.5	1.3	
1/n	1.0	1.4	
Corr. Coef. r	0.87	0.79	
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	59	34	
1.0	5.5	1.3	
0.1	0.50	0.05	
0.01	0.047	0.002	

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	1,800	21,000	>100,000
0.1		1,900	23,000
0.01			2,100

GRANULAR CARBON COLUMN

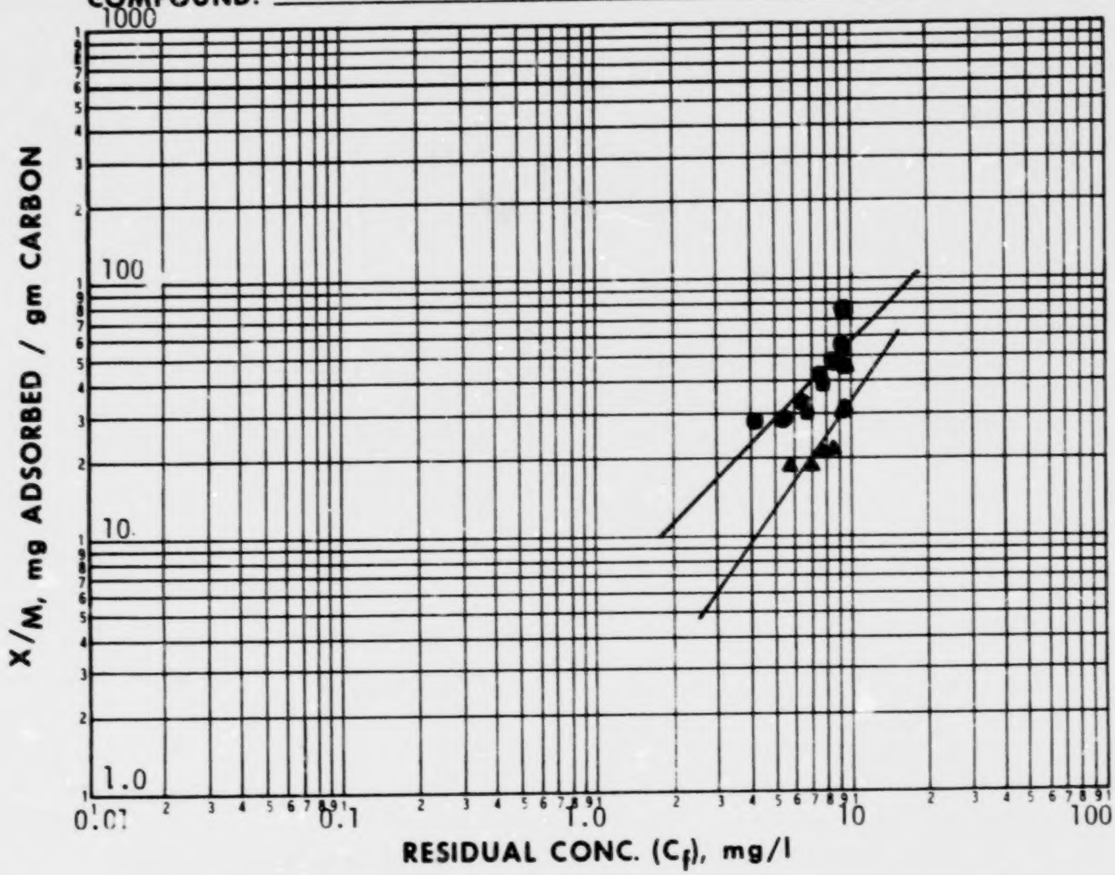
C_o, mg/l	
1.0	183
0.1	198
0.01	215

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 269 nm

REMARKS:

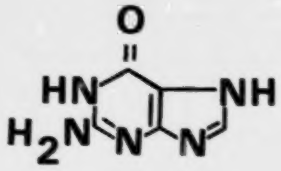
COMPOUND: 5-Fluorouracil



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	9.81			9.86			9.83		
5	9.43	0.38	76	9.48	0.38	76	9.60	0.23	46
10	9.26	0.55	55	9.33	0.53	53	9.52	0.31	31
25	8.59	1.22	49	8.66	1.20	48	9.07	0.76	30
50	7 76	2.05	41	7.93	1.93	39	8.71	1.12	22
100	6.47	3.34	33	6.84	3.02	30	7.76	2.07	21
150	5.39	4.42	29	5.47	4.39	29	6.98	2.85	19
200	4.09	5.72	28	4.13	5.73	28	5.84	3.99	19

COMPOUND: Guanine

STRUCTURE:



FORMULA: $C_5H_5N_5O$ **MOL. WT.** 151.13

FREUNDLICH PARAMETERS	**pH**		
	3.0	pH 7 and 9 pooled	
K	75	120	
1/n	0.48	0.40	
Corr. Coef. r	0.98	0.98	
INITIAL CONC. mg/l	**ADSORPTION CAPACITY, mg/gm**		
10	230	300	
1.0	75	120	
0.1	25	49	
0.01	8.0	20	

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON
C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	19	51	130
0.1		4.7	13
0.01			1.2

GRANULAR CARBON COLUMN

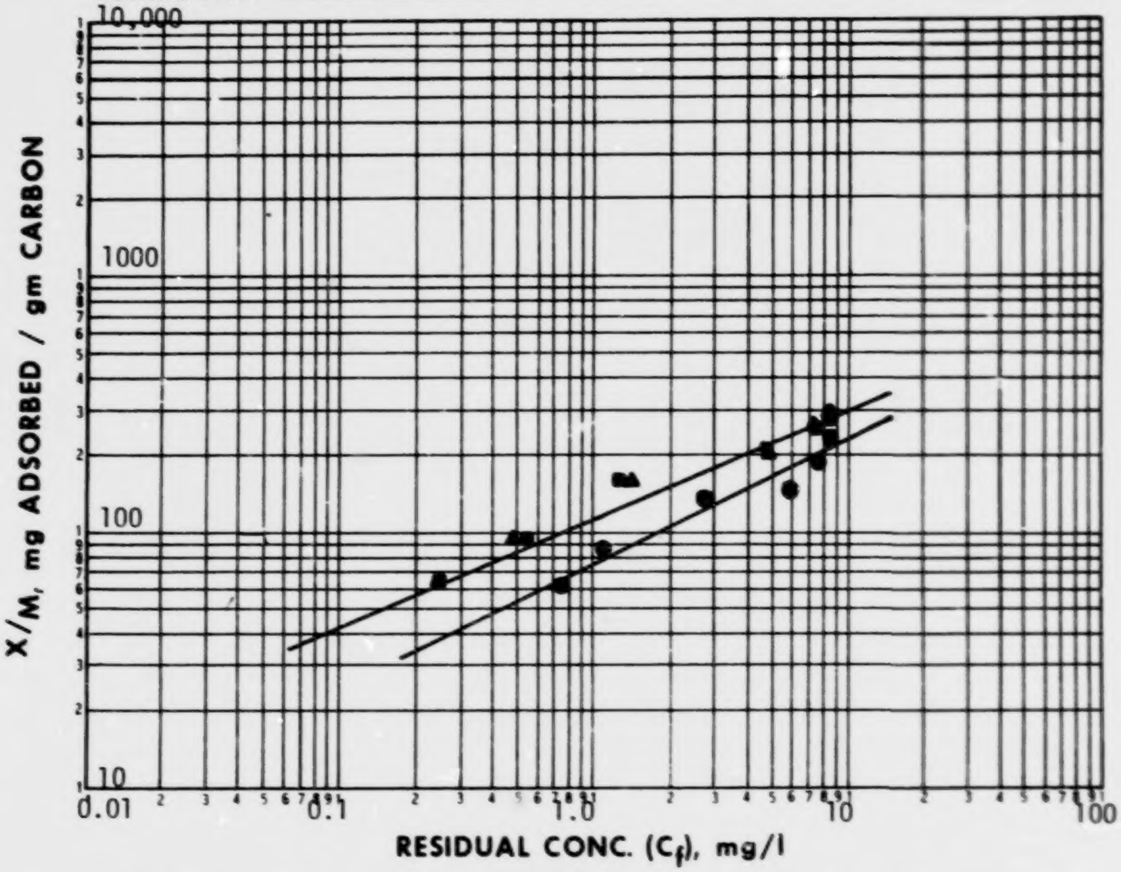
C_o, mg/l	
1.0	8.2
0.1	2.0
0.01	0.5

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 247 nm

REMARKS:

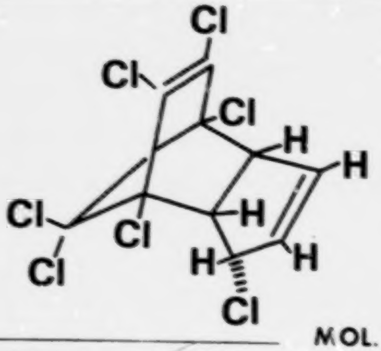
COMPOUND: Guanine



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	9.87			9.92			9.88		
5	8.70	1.17	234	8.53	1.39	278	8.40	1.48	296
10	7.93	1.94	194	7.34	2.58	258	7.21	2.67	267
25	6.00	3.87	155	4.76	5.16	206	4.86	5.02	201
50	2.83	7.04	141	1.30	8.62	172	1.47	8.41	168
100	1.22	8.65	87	0.54	9.38	94	0.49	9.39	94
150	0.77	9.10	61	0.25	9.67	64	0.24	9.64	64

COMPOUND: Heptachlor

STRUCTURE:



FORMULA: $C_{10}H_5Cl_7$ **MOL. WT.** 373.5

FREUNDLICH PARAMETERS	pH		
	5.3		
K	1220		
1/n	0.95		
Corr. Coef. r	0.78		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	1220		
0.1	140		
0.01	15		
0.001	1.7		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON
C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	6.6	64	580
0.1		5.9	57
0.01			5.2

GRANULAR CARBON COLUMN

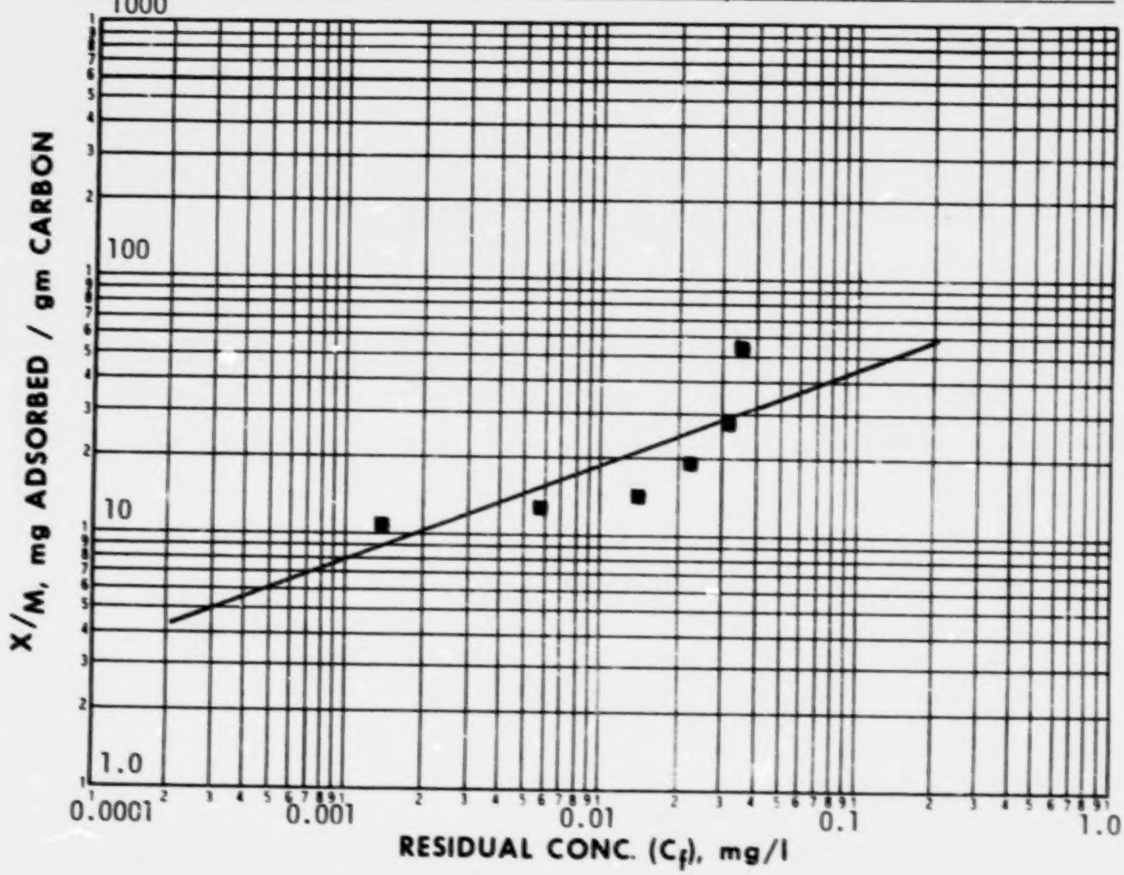
C_o, mg/l	
1.0	0.8
0.1	0.7
0.01	0.7

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent extraction - G. C.

REMARKS:

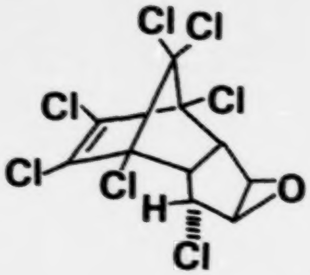
COMPOUND: Heptachlor



	● pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	0.169								
1.0	0.0368	0.1322	132						
2.5	0.0353	0.1337	53.5						
5	0.0311	0.1379	27.6						
7.5	0.0217	0.1473	19.6						
10	0.0137	0.1553	15.5						
12.5	0.0058	0.1632	13.1						

COMPOUND: Heptachlor epoxide

STRUCTURE:



FORMULA: $C_{10}H_5Cl_7O$ **MOL. WT.** 389.32

FREUNDLICH PARAMETERS	pH		
	5.3		
K	1038		
1/n	0.70		
Corr. Coef. r	0.98		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	1038		
0.1	210		
0.01	41		
0.001	8.3		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	4.3	24	120
0.1		2.2	12
0.01			1.1

GRANULAR CARBON COLUMN

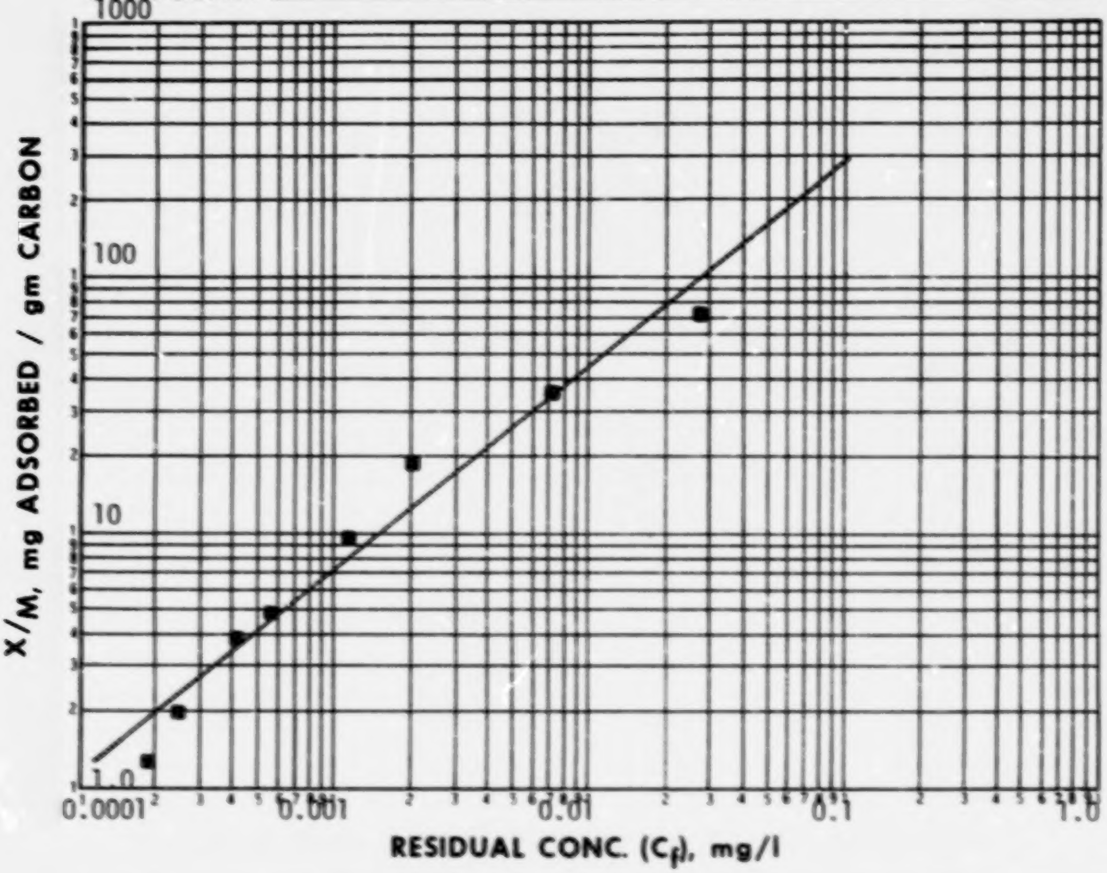
C_o, mg/l	
1.0	1.0
0.1	0.5
0.01	0.2

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent extraction - G. C.

REMARKS:

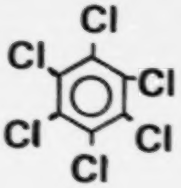
COMPOUND: Heptachlor epoxide



	● pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	0.0985								
1.0	0.0279	0.0706	70.6						
2.5	0.00727	0.0912	36.5						
5	0.00204	0.0965	19.3						
10	0.00122	0.0973	9.73						
20	0.00057	0.0979	[illegible].90						
25	0.00041	0.0981	3.92						

COMPOUND: Hexachlorobenzene

STRUCTURE:



FORMULA: C_6Cl_6 **MOL. WT.** 284.78

FREUNDLICH PARAMETERS	pH		
	5.3		
K	450		
1/n	0.60		
Corr. Coef. r	0.94		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	450		
0.1	110		
0.01	28		
0.001	7.1		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	8.0	35	140
0.1		3.2	14
0.01			1.3

GRANULAR CARBON COLUMN

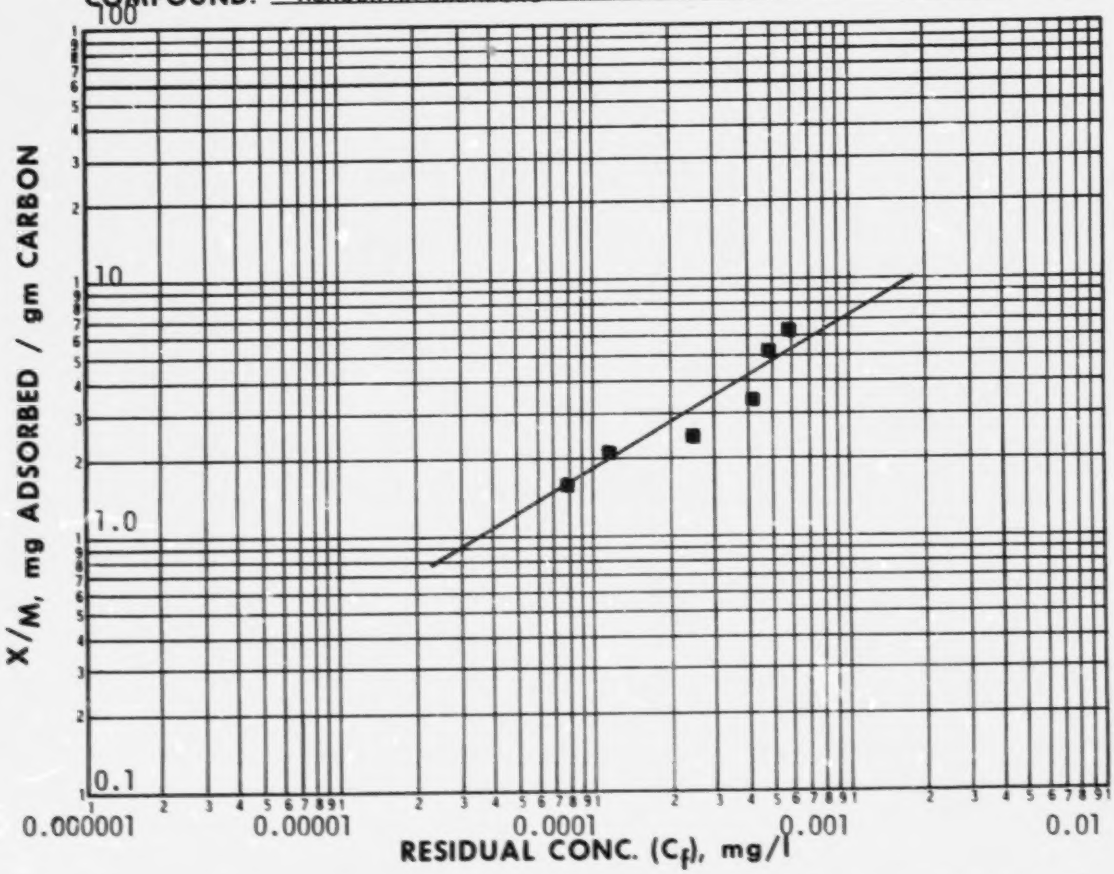
C_o, mg/l	
1.0	2.2
0.1	1.0
0.01	0.4

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent Extraction - G.C.

REMARKS:

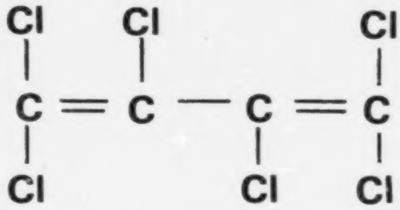
COMPOUND: Hexachlorobenzene



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f*	$C_o-C_f=X$*	X/M	C_f	C_o-C_f=X	X/M	C_f	C_o-C_f=X	X/M
0	0.753								
0.025	0.597	0.156	6.24						
0.05	0.492	0.261	5.22						
0.1	0.409	0.344	3.44						
0.2	0.254	0.499	2.50						
0.3	0.120	0.633	2.11						
0.4	0.079	0.674	1.69						
* x 10^3									

COMPOUND: Hexachlorobutadiene

STRUCTURE:



FORMULA: C_4Cl_6 **MOL. WT.** 260.76

FREUNDLICH PARAMETERS	pH		
K	258		
1/n	0.45		
Corr. Coef. r	1.00		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	258		
0.1	91		
0.01	32		
0.001	11		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	48	150	430
0.1		14	43
0.01			3.9

GRANULAR CARBON COLUMN

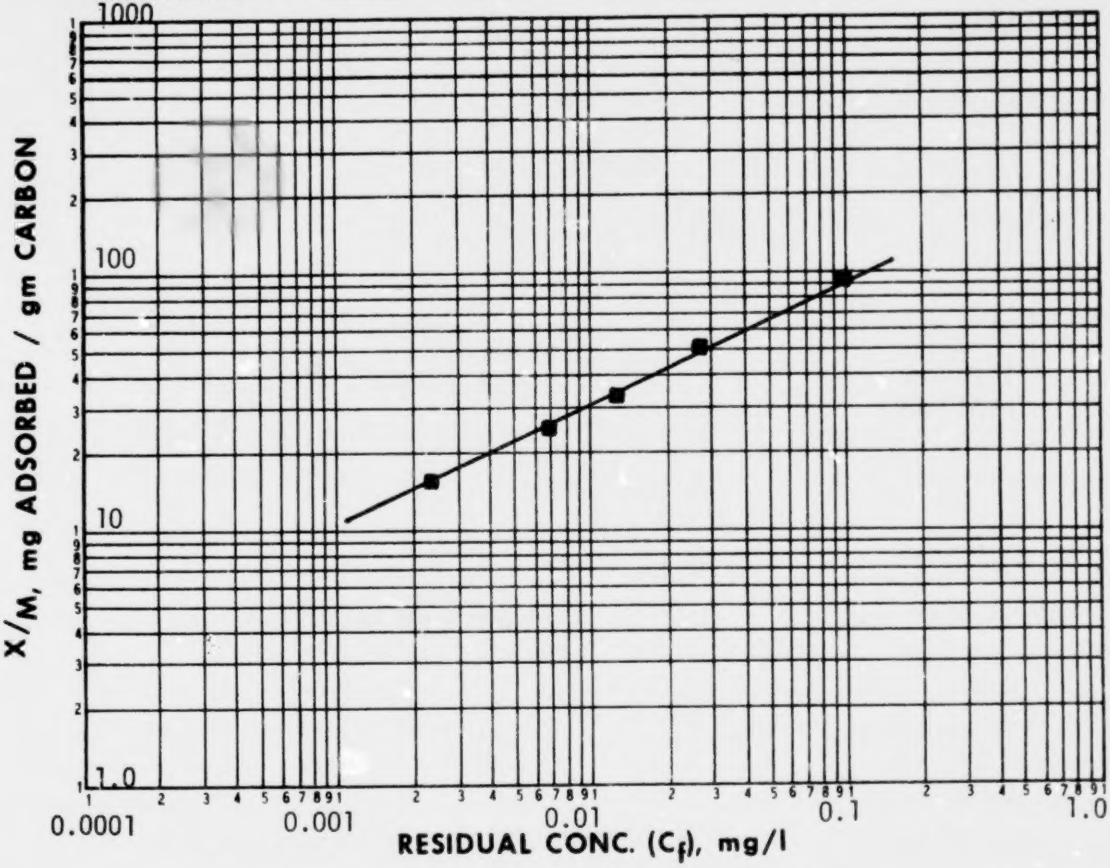
C_o, mg/l	
1.0	3.9
0.1	1.1
0.01	0.3

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G. C. Purge and Trap

REMARKS:

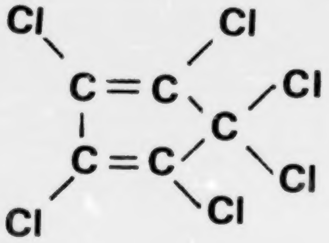
COMPOUND: Hexachlorobutadiene



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	1.000								
9.6	0.098	0.902	93.8						
19.2	0.027	0.973	50.6						
28.9	0.013	0.987	34.2						
38.5	0.007	0.993	25.8						
57.7	0.002	0.998	17.3						

COMPOUND: Hexachlorocyclopentadiene

STRUCTURE:



FORMULA: C_5Cl_6 **MOL. WT.** 272.77

FREUNDLICH PARAMETERS	pH		
	5.3		
K	370		
1/n	0.17		
Corr. Coef. r	0.99		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	370		
0.1	250		
0.01	180		
0.001	112		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	3.6	5.9	8.9
0.1		0.54	0.88
0.01			0.08

GRANULAR CARBON COLUMN

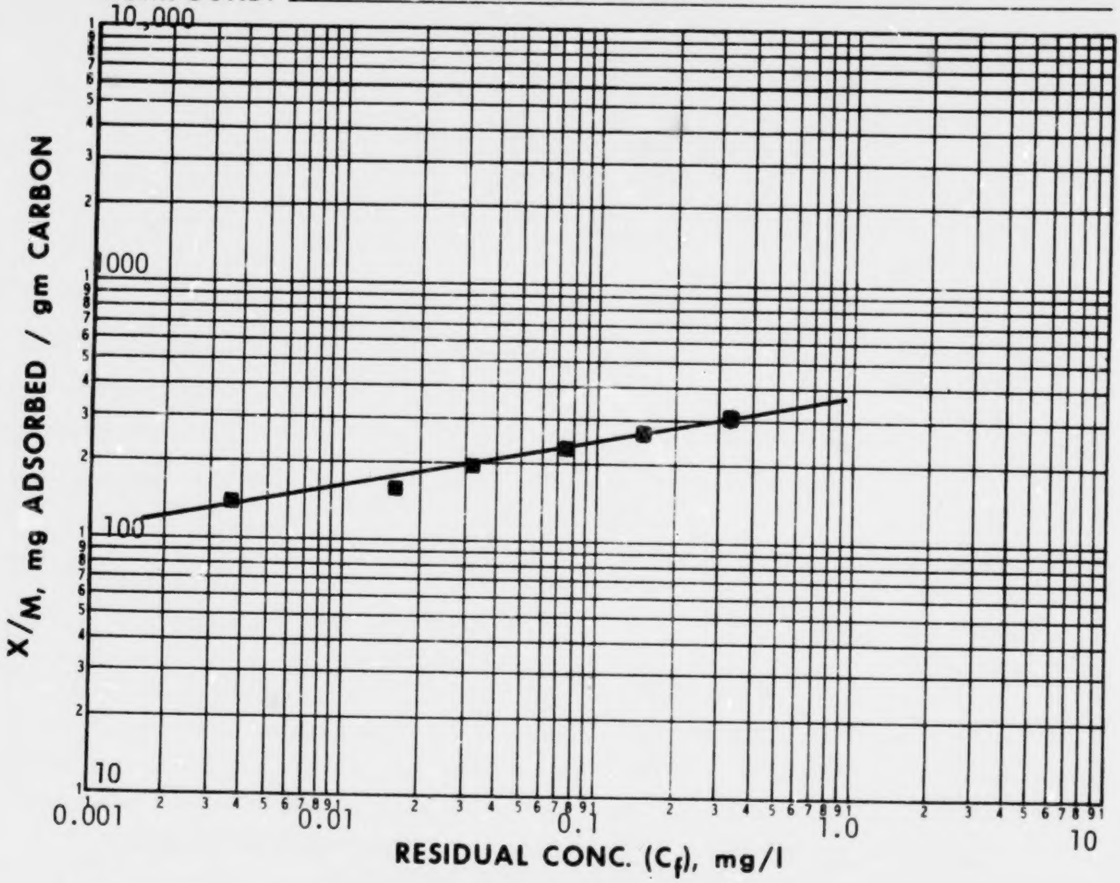
C_o, mg/l	
1.0	2.7
0.1	0.40
0.01	0.06

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G. C. Purge and Trap

REMARKS:

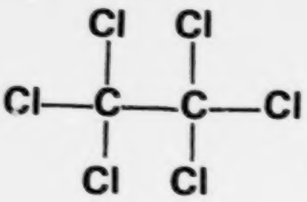
COMPOUND: Hexachlorocyclopentadiene



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	0.800								
1.54	0.327	0.473	307						
2.31	0.159	0.641	278						
3.08	0.074	0.726	236						
3.85	0.031	0.769	200						
4.62	0.017	0.783	170						
5.38	0.004	0.796	148						

COMPOUND: Hexachloroethane

STRUCTURE:



$\mathrm{Cl_3C{-}CCl_3}$

FORMULA: C_2Cl_6 **MOL. WT.** 236.74

FREUNDLICH PARAMETERS	pH		
	5.3		
K	96.5		
1/n	0.38		
Corr. Coef. r	0.93		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	97		
0.1	41		
0.01	17		
0.001	7.2		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	20	60	140
0.1		5.3	14
0.01			1.3

GRANULAR CARBON COLUMN

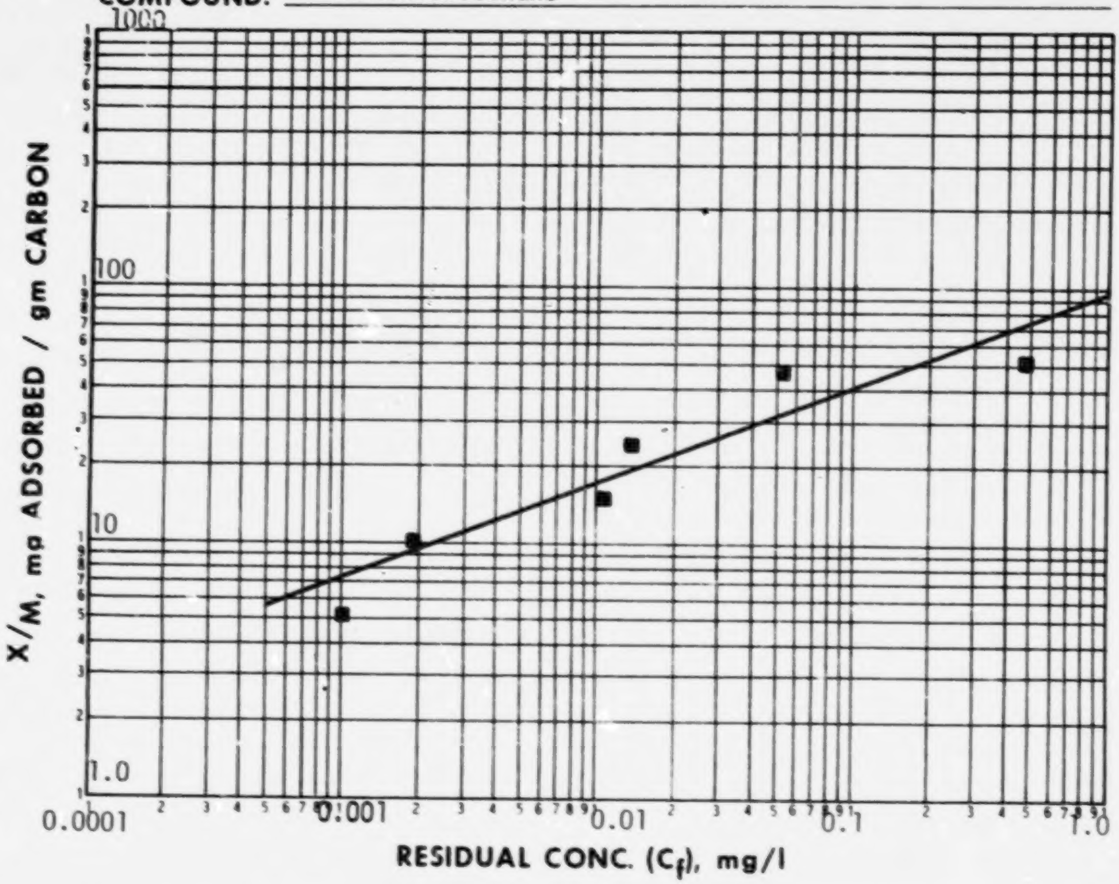
C_o, mg/l	
1.0	10
0.1	2.5
0.01	0.6

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G.C. Purge and Trap

REMARKS: Compound contained an impurity which was estimated to be 20% using integrated areas from computer output.

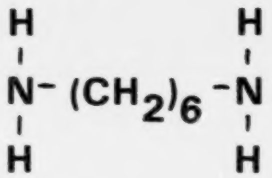
COMPOUND: Hexachloroethane



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	0.974								
9.6	0.484	0.490	50.9						
19.2	0.051	0.923	48.0						
38.5	0.014	0.960	25.0						
58	0.011	0.963	16.7						
96	0.002	0.972	10.1						
192	0.0010	0.973	5.06						

COMPOUND: Hexamethylenediamine

STRUCTURE:



$$H_2N-(CH_2)_6-NH_2$$

FORMULA: $C_6H_{16}N_2$ **MOL. WT.** 116.12

FREUNDLICH PARAMETERS	pH		
K			
1/n			
Corr. Coef. r			
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l			

GRANULAR CARBON COLUMN

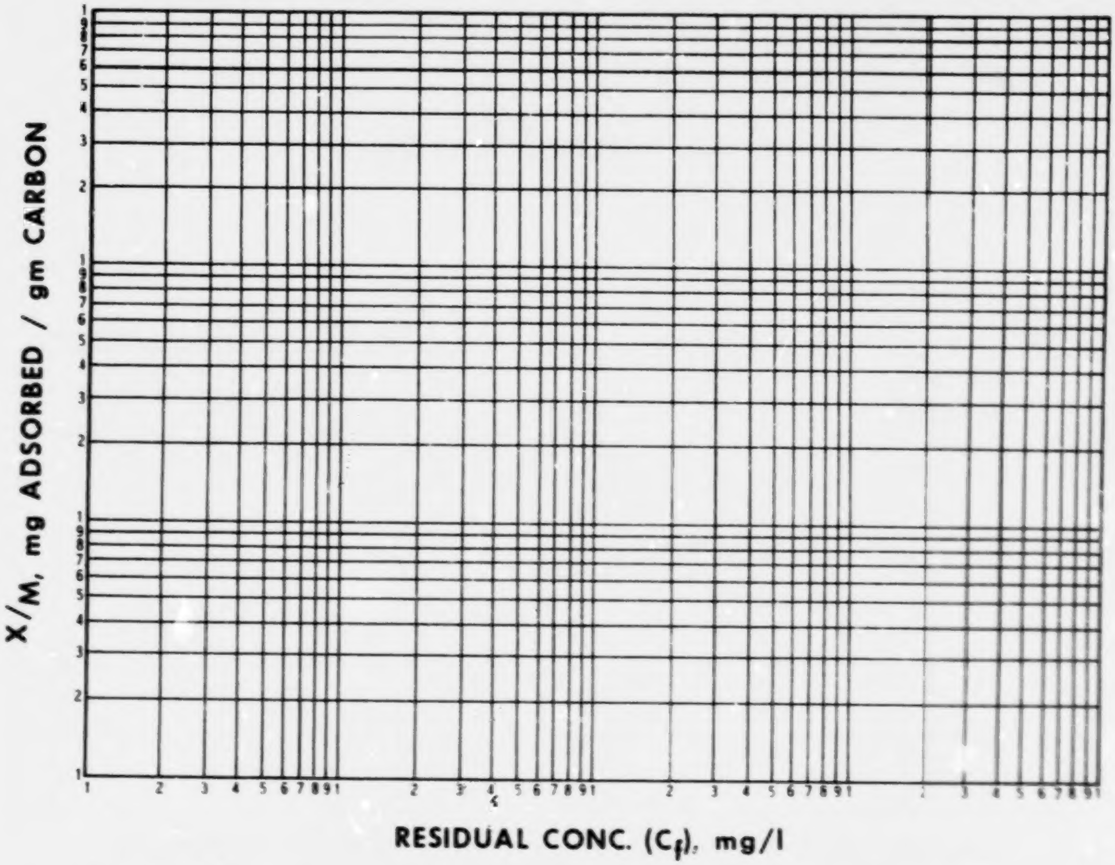
C_o, mg/l	

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Total Organic Carbon

REMARKS: Not adsorbed

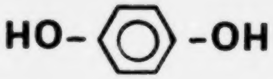
COMPOUND: Hexamethylenediamine



	pH= 3.0			pH= 7.01			pH= 8.95		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	12.2			11.8			11.6		
5	11.4			11.8			11.4		
10	11.2			11.2			13.2		
25	10.6			11.2			11.6		
50	11.6			12.0			11.4		
100	10.6			11.4			11.0		
150	11.4			12.0			11.2		
200	12.0			11.0			10.6		

COMPOUND: Hydroquinone

STRUCTURE:



FORMULA: $C_6H_6O_2$ **MOL. WT.** 110.12

FREUNDLICH PARAMETERS	pH		
	3.0		
K	90		
1/n	0.25		
Corr. Coef. r	0.93		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	160		
1.0	90		
0.1	51		
0.01	29		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	18	35	62
0.1		3.2	6.2
0.01			0.56

GRANULAR CARBON COLUMN

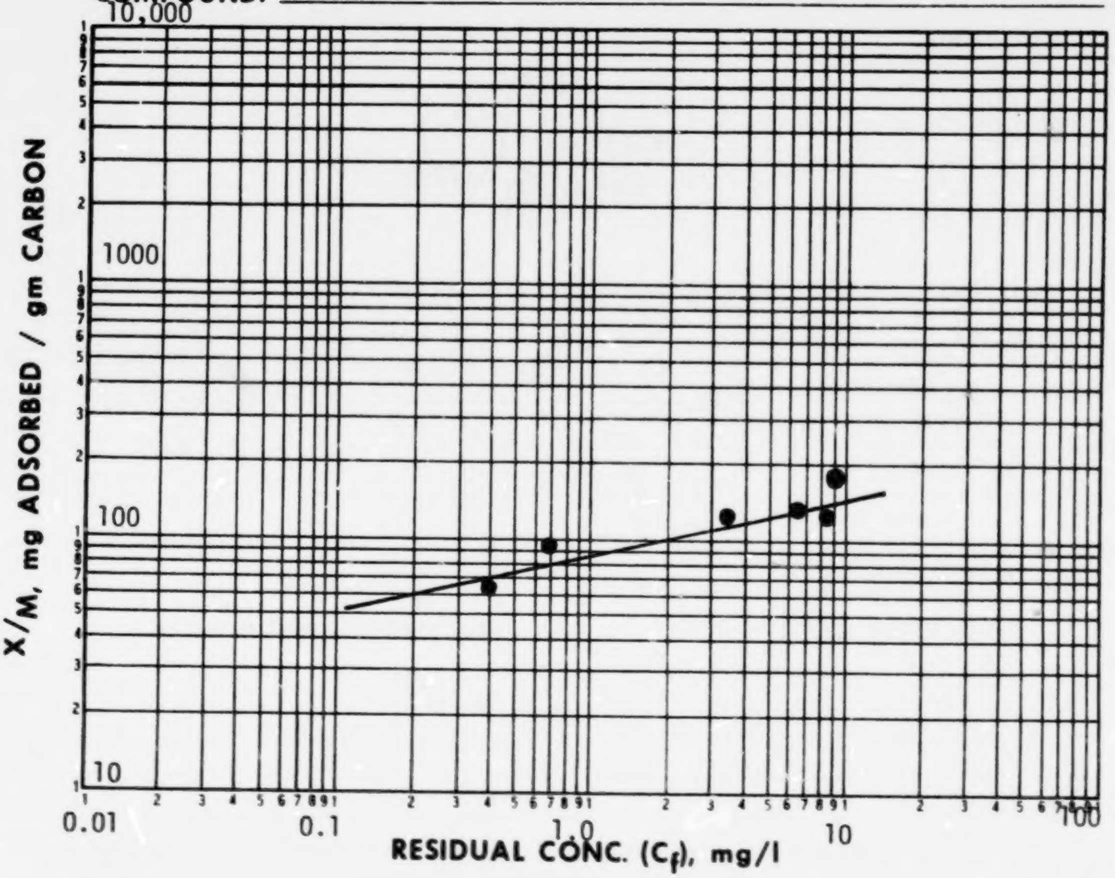
C_o, mg/l	
1.0	11
0.1	2.0
0.01	0.3

(a) Carbon doses in mg/l at pH 3.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 288 nm

REMARKS: Hydroquinone is unstable at pH 7 and 9: colored products are formed.

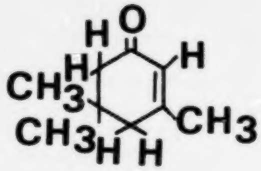
COMPOUND: Hydroquinone



	● pH= 3.0			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	10.00								
5	9.1	0.9	180						
10	8.7	1.3	130						
25	6.6	3.4	136						
50	3.4	6.6	132						
100	0.7	9.3	93						
150	0.4	9.6	64						

COMPOUND: Isophorone

STRUCTURE:



FORMULA: $C_9H_{14}O$ **MOL. WT.** 138.21

FREUNDLICH PARAMETERS	pH		
	5.5		
K	32		
1/n	0.39		
Corr. Coef. r	0.93		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10.0	78.3		
1.0	32.0		
0.1	13.1		
0.01	5.4		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	70	19[illegible]	[illegible]
0.1		17[illegible]	[illegible]
0.01			4.2

GRANULAR CARBON COLUMN

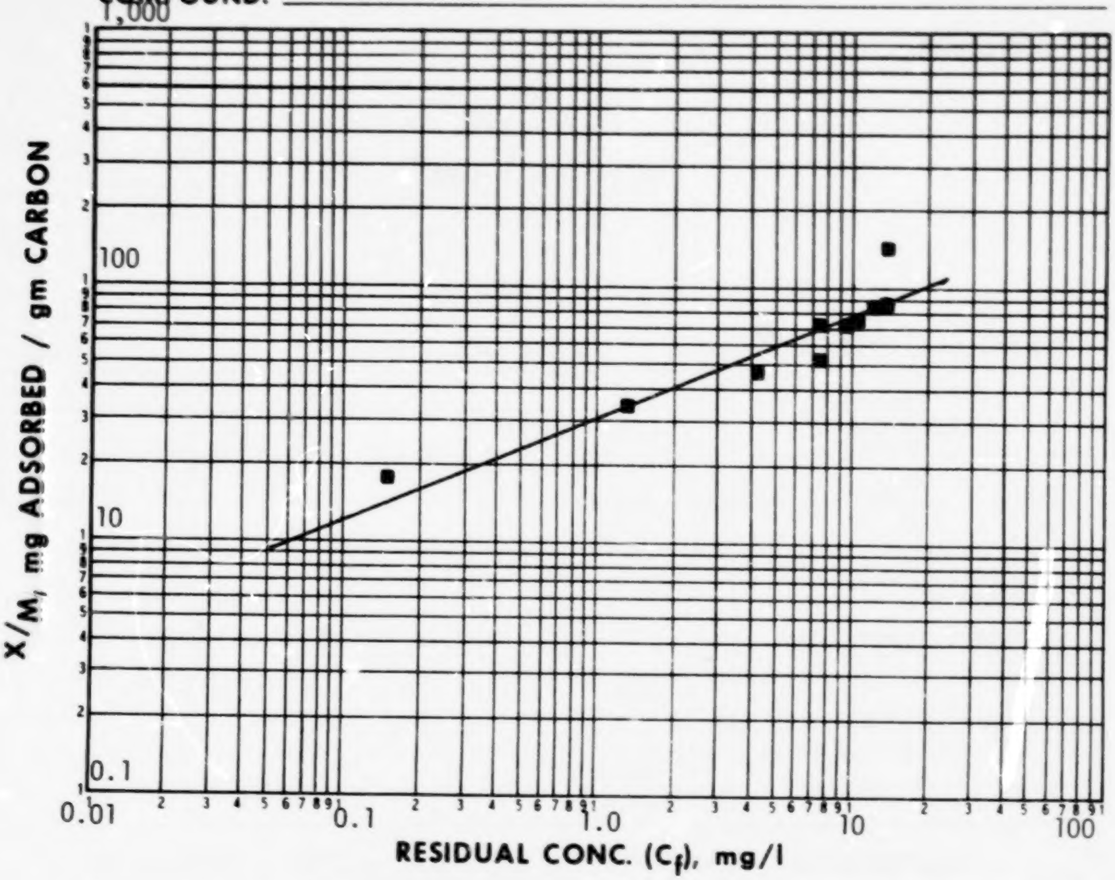
C_o, mg/l	
[illegible]	31
0.1	7.6
0.01	1.9

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Total Carbon

REMARKS:

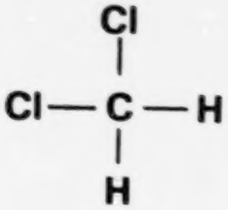
COMPOUND: Isophorone



	■ pH= 5.5			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	18.10								
25	14.32	3.78	151.2						
50	13.71	4.39	87.8						
75	11.74	6.36	84.8						
100	10.60	7.50	75.0						
125	9.31	8.79	70.32						
150	7.50	10.60	70.67						
200	7.61	10.49	52.45						
300	4.09	14.01	46.70						
500	1.30	16.80	33.60						
1000	0.162	17.94	17.94						

COMPOUND: Methylene chloride

STRUCTURE:



$$\begin{array}{c} \mathrm{Cl} \\ | \\ \mathrm{Cl}-\mathrm{C}-\mathrm{H} \\ | \\ \mathrm{H} \end{array}$$

FORMULA: CH_2Cl_2 **MOL. WT.** 84.94

FREUNDLICH PARAMETERS	pH		
	5.8		
K	1.30		
1/n	1.16		
Corr. Coef. r	0.96		
INITIAL CONC. mg/l	**ADSORPTION CAPACITY, mg/gm**		
10	19.0		
1.0	1.3		
0.1	0.09		
0.01	0.006		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	10,000	>100,000	>100,000
0.1		14,000	>100,000
0.01			21,000

GRANULAR CARBON COLUMN

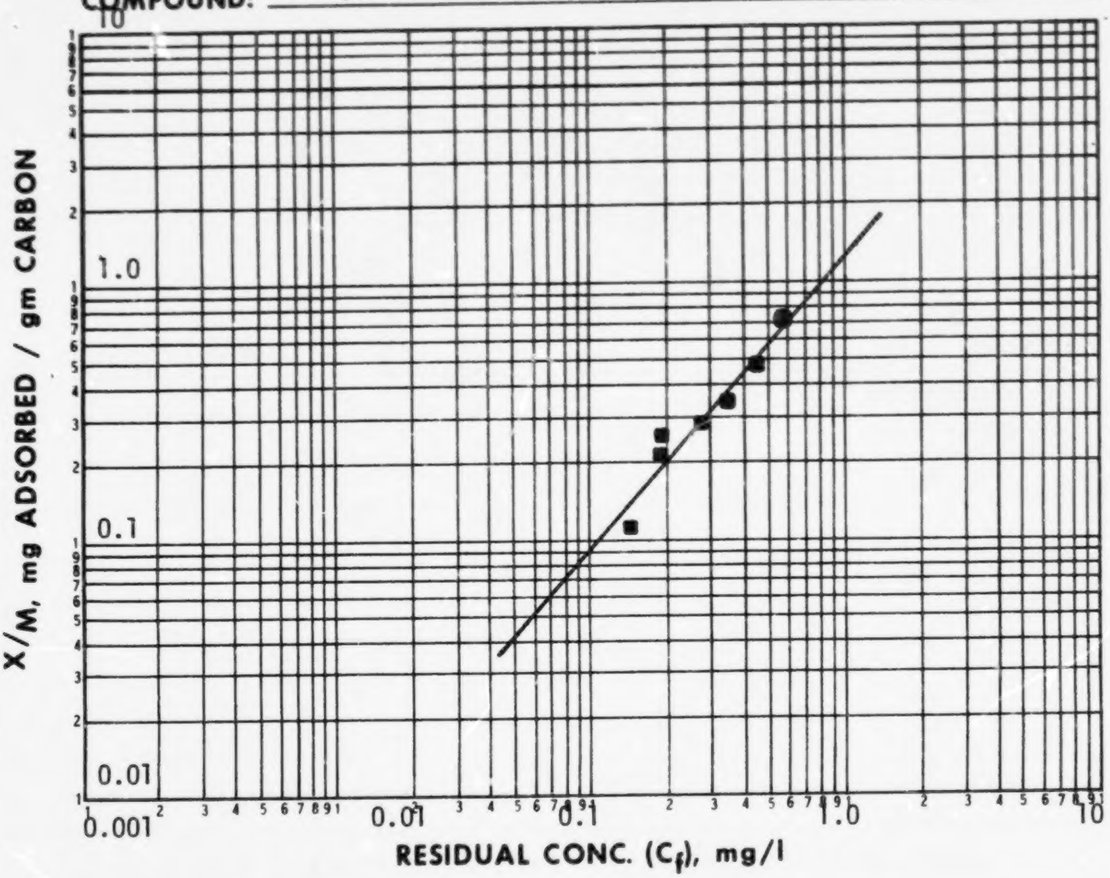
C_o, mg/l	
1.0	770
0.1	1,100
0.01	1,700

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G.C. - Purge and Trap

REMARKS:

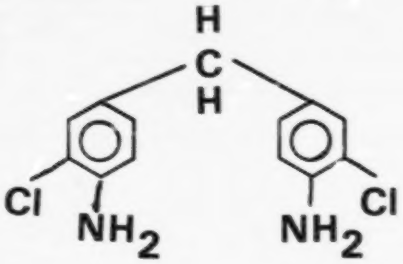
COMPOUND: Methylene chloride



	■ pH= 5.8			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	1.0								
578	0.582	0.42	0.72						
1154	0.451	0.55	0.48						
1923	0.335	0.66	0.35						
2500	0.278	0.72	0.29						
3077	0.199	0.80	0.26						
3846	0.199	0.80	0.21						
6731	0.162	0.84	0.12						

COMPOUND: 4,4'-Methylene-Bis(2-chloroaniline)

STRUCTURE:



FORMULA: $C_{13}H_{12}Cl_2N_2$ **MOL. WT.** 264.28

FREUNDLICH PARAMETERS	pH		
	7.5		
K	190		
1/n	0.64		
Corr. Coef. r	0.90		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	820		
1.0	190		
0.1	43		
0.01	10		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	21	99	440
0.1	-	9.0	43
0.01	-	-	3.9

GRANULAR CARBON COLUMN

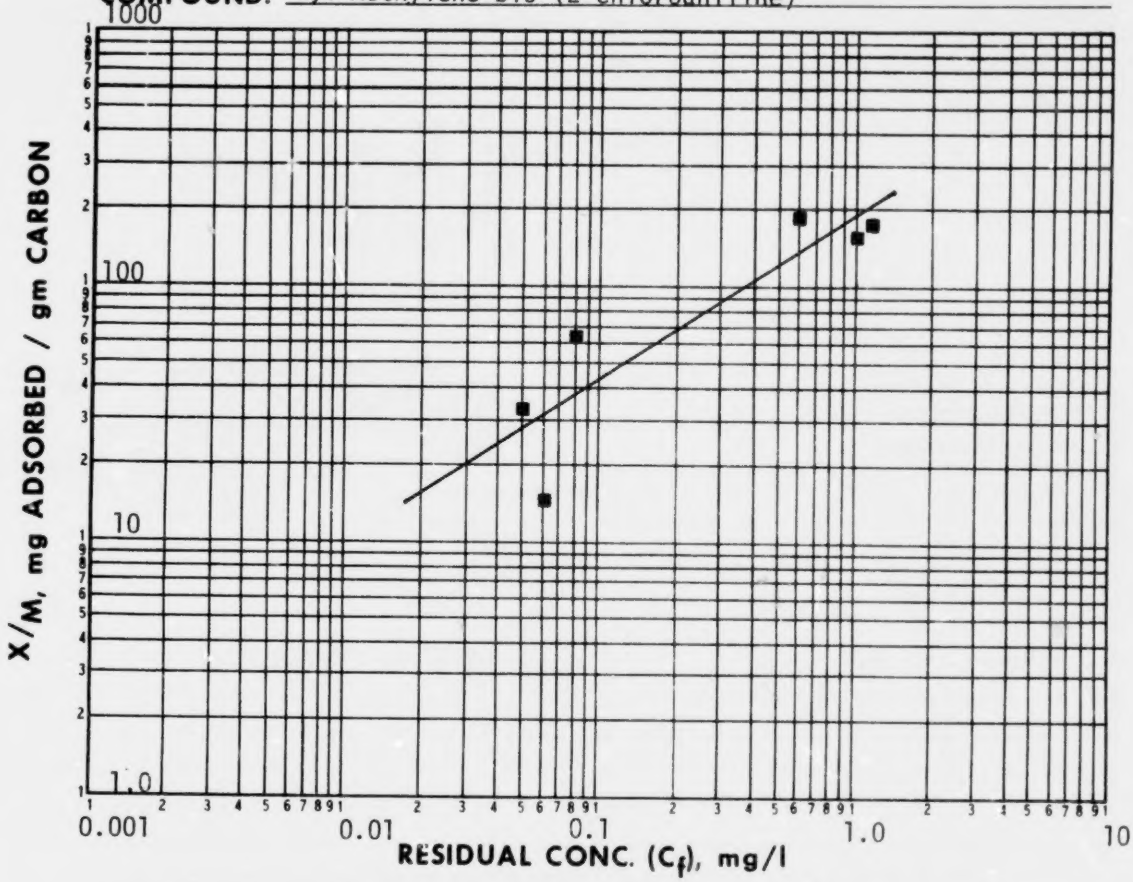
C_o, mg/l	
1.0	5.3
0.1	2.3
0.01	1.0

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 240 nm

REMARKS: OSHA regulated carcinogen.

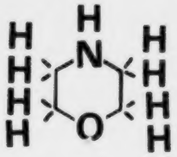
COMPOUND: 4,4'Methylene-bis-(2-chloroaniline)



	■ pH= 7.5			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	1.38								
1.1	1.18	0.20	177						
2.3	1.00	0.38	168						
4.1	0.60	0.78	193						
20.5	0.08	1.30	64						
40.1	0.05	1.33	33						
80.3	0.07	1.31	16						

COMPOUND: Morpholine

STRUCTURE:



FORMULA: C_4H_9NO **MOL. WT.** 87.12

FREUNDLICH PARAMETERS	pH		
K			
1/n			
Corr. Coef. r			
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l			

GRANULAR CARBON COLUMN

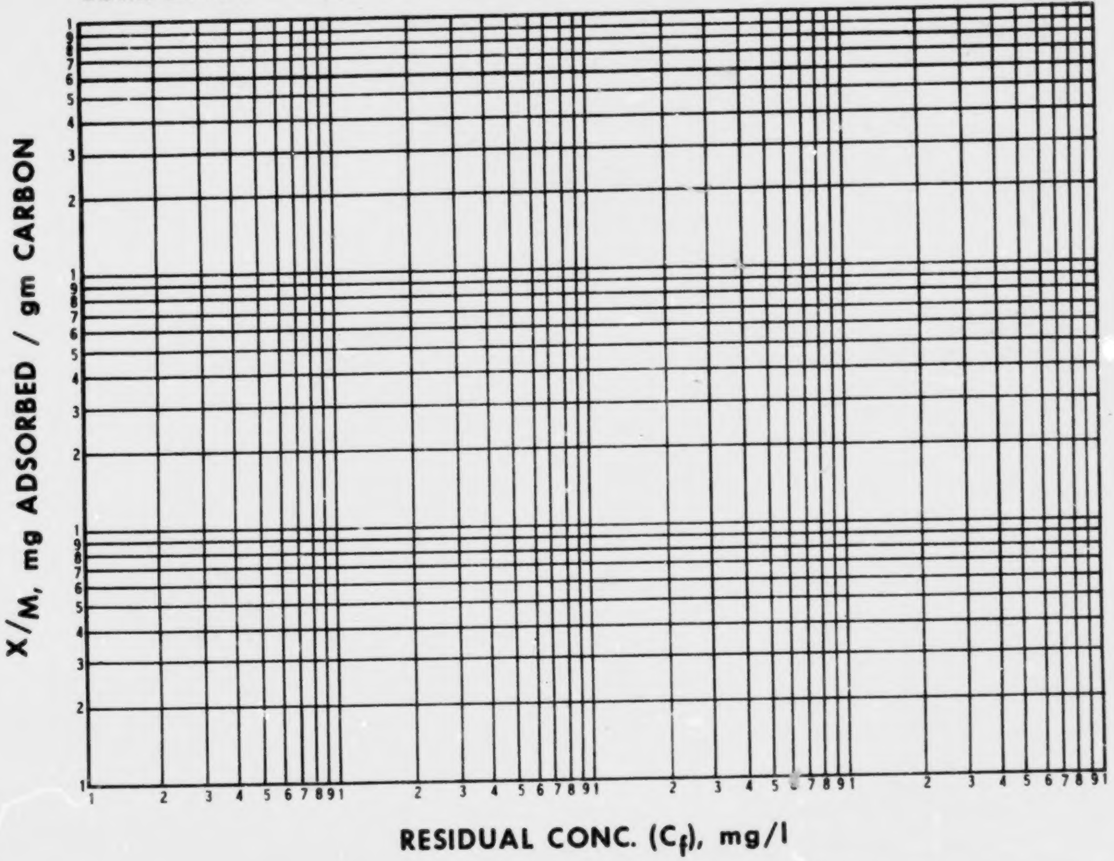
C_o, mg/l	

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Total Organic Carbon

REMARKS: Not adsorbed

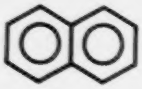
COMPOUND: Morpholine



	pH= 3.0			pH= 7.0			pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	11.4			13.6			12.6		
5	12.0			12.8			12.2		
10	11.6			12.2			11.2		
25	11.2			11.8			12.2		
50	11.8			12.0			13.2		
100	11.6			11.2			12.6		
150	12.2			11.4			11.0		
200	12.2			10.4			10.8		

COMPOUND: Naphthalene

STRUCTURE:



FORMULA: $C_{10}H_8$ **MOL. WT.** 128.18

FREUNDLICH PARAMETERS	pH		
	5.6		
K	132		
1/n	0.42		
Corr. Coef. r	0.96		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	132		
0.1	50		
0.01	19		
0.001	7.3		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	18	52	140
0.1		4.7	13
0.01			1.2

GRANULAR CARBON COLUMN

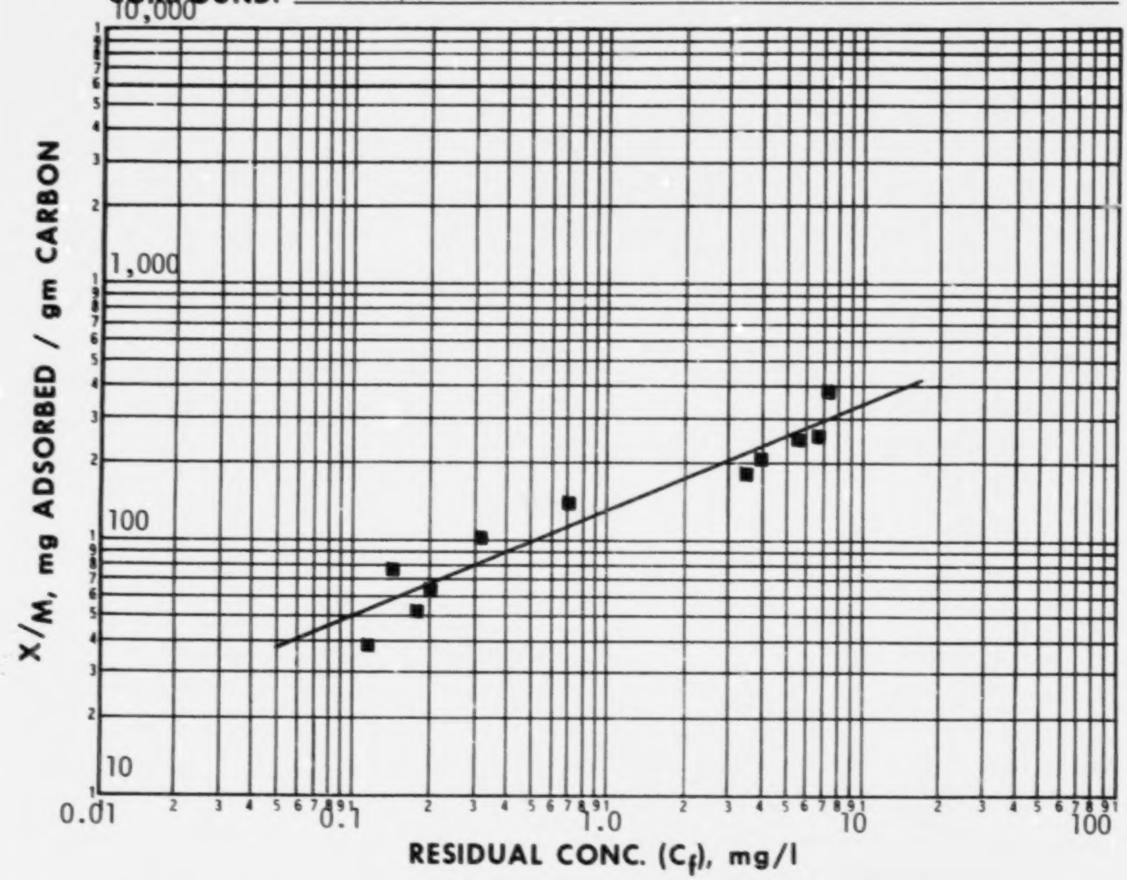
C_o, mg/l	
1.0	7.6
0.1	2.0
0.01	0.5

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 275.5 nm.

REMARKS:

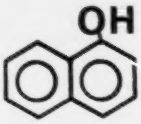
COMPOUND: Naphthalene



	■ pH= 5.6			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	8.07								
2.5	7.10	0.970	388						
5	6.74	1.33	266						
10	5.52	2.55	255						
20	3.97	4.10	205						
25	3.48	4.59	184						
50	0.70	7.37	147						
75	0.31	7.76	104						
100	0.15	7.92	79						
125	0.20	7.87	63						
150	0.18	7.89	53						
200	0.12	7.95	40						

COMPOUND: α - Naphthol

STRUCTURE:



FORMULA: $C_{10}H_8O$ **MOL. WT.** 144.2

FREUNDLICH PARAMETERS	pH		
	All data pooled		
K	180		
1/n	0.32		
Corr. Coef. r	0.90		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	370		
1.0	180		
0.1	85		
0.01	41		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	10	23	48
0.1		2.1	4.7
0.01			0.43

GRANULAR CARBON COLUMN

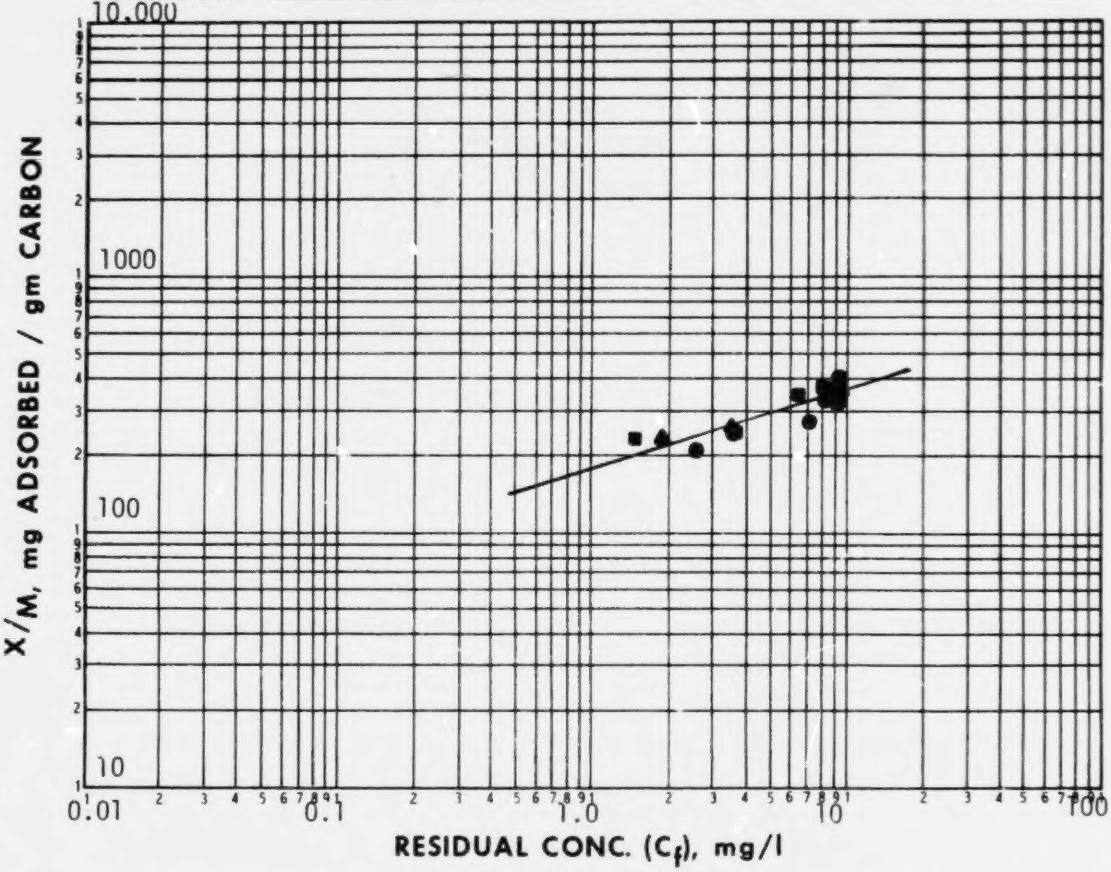
C_o, mg/l	
1.0	5.7
0.1	1.2
0.01	0.2

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 286 nm

REMARKS:

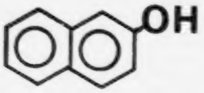
COMPOUND: α - Naphthol



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	C_o-C_f=X	X/M	C_f	C_o-C_f=X	X/M
0	9.89			9.88			9.96		
1.0	9.49	0.40	400	9.50	0.38	380	9.59	0.37	370
2.5	9.07	0.82	328	8.96	0.92	368	9.14	0.82	328
5	8.22	1.67	334	8.00	1.88	376	8.16	1.80	360
10	7.13	2.67	276	6.39	3.49	349	6.77	3.19	319
25	3.72	6.17	247	3.73	6.15	246	3.62	6.70	268
35	2.65	7.24	207	1.64	8.24	235	1.91	8.05	230

COMPOUND: β - Naphthol

STRUCTURE:



FORMULA: $C_{10}H_8O$ **MOL. Wt.** 144.2

FREUNDLICH PARAMETERS	pH		
	All data pooled		
K	200		
1/n	0.26		
Corr. Coef. r	0.89		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	360		
1.0	200		
0.1	110		
0.01	59		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	8.4	17	31
0.1		1.5	3.0
0.01			0.28

GRANULAR CARBON COLUMN

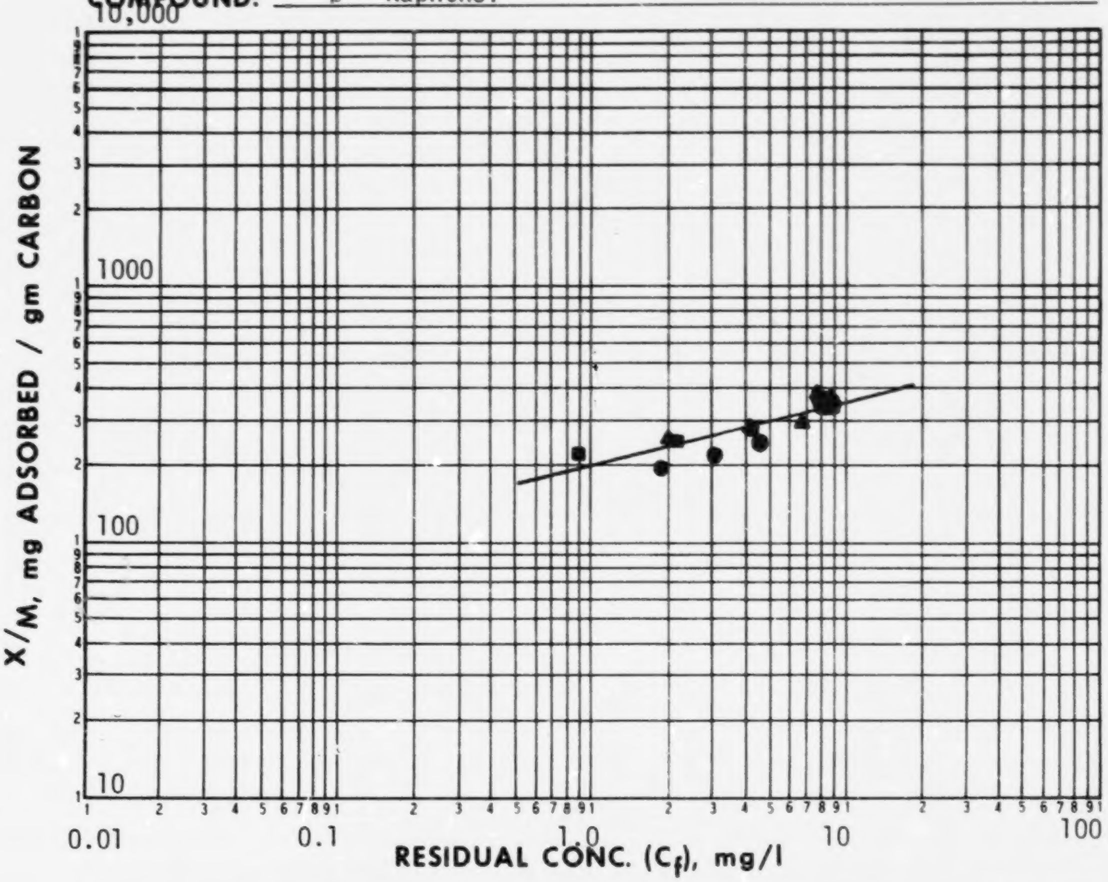
C_o, mg/l	
1.0	5.1
0.1	1.0
0.01	0.2

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 273 nm

REMARKS:

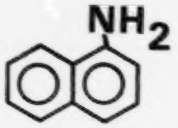
COMPOUND: β - Naphthol



	● pH=3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	9.77			9.73			9.73		
2.5	8.90	0.87	348	8.87	0.86	344	8.80	0.93	372
5	8.09	1.68	336	7.85	1.88	376	7.81	1.92	384
10							6.75	2.98	298
20	4.74	5.03	251	4.16	5.57	279	4.12	5.61	281
30	3.12	6.65	222	2.21	7.52	250	1.96	7.77	259
40	1.94	7.83	196	0.90	8.83	221			

COMPOUND: α - Naphthylamine

STRUCTURE:



FORMULA: $C_{10}H_9N$ **MOL. WT.** 143.18

FREUNDLICH PARAMETERS	pH		
	3.0	pH 7 and 9 pooled	
K	140	160	
1/n	0.25	0.34	
Corr. Coef. r	0.98	0.98	
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	250	360	
1.0	140	160	
0.1	79	75	
0.01	44	34	

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	12	29	64
0.1		2.6	6.3
0.01			0.58

GRANULAR CARBON COLUMN

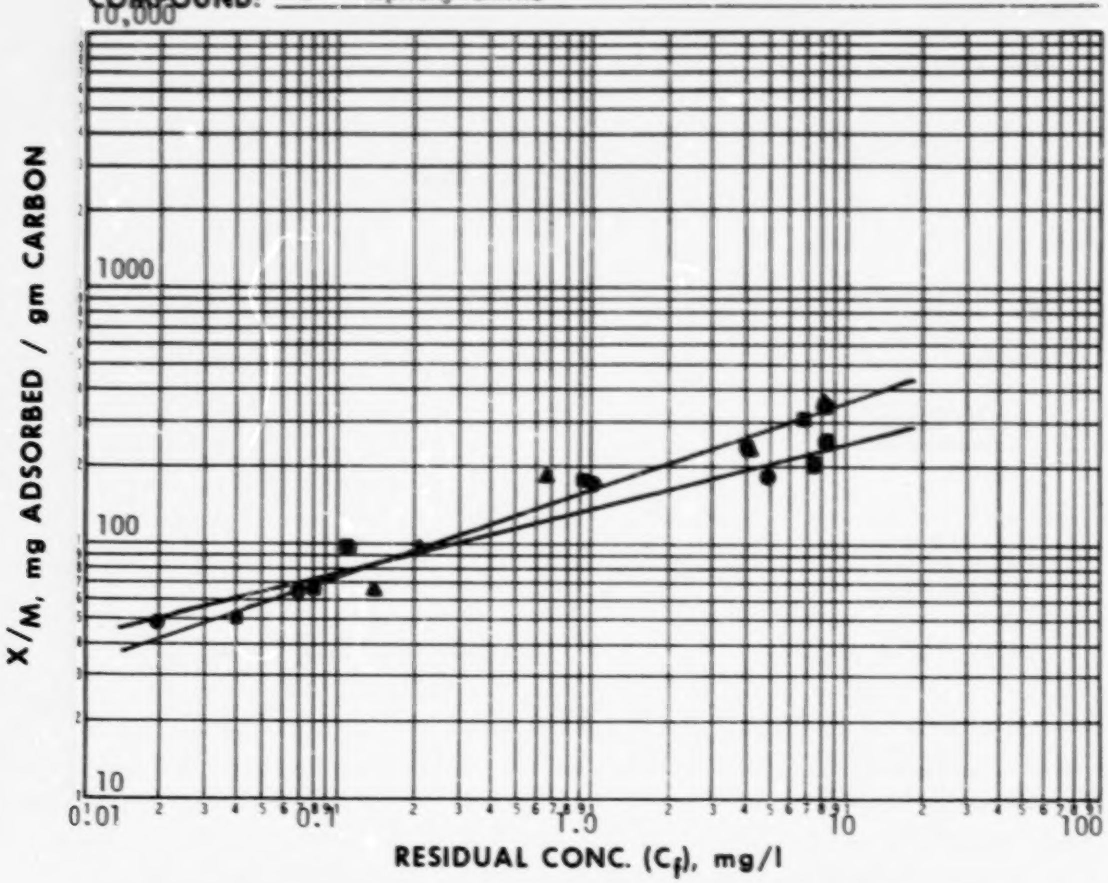
C_o, mg/l	
1.0	6.1
0.1	1.3
0.01	0.3

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 304 nm

REMARKS: OHSA regulated carcinogen

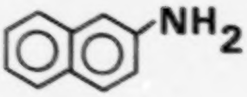
COMPOUND: α - Naphthylamine



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	9.74			9.94			9.95		
5	8.43	1.31	262	8.22	1.72	344	8.16	1.79	358
10	7.73	2.01	201	6.93	3.01	301	6.94	3.01	301
25	4.97	4.77	191	4.00	5.94	238	4.11	5.84	234
50	1.05	8.69	174	0.92	9.02	180	0.68	9.27	185
100	0.12	9.62	96	0.11	9.83	98	0.21	9.74	97
150	0.07	9.67	65	0.08	9.86	66	0.14	9.81	65
200	0.02	9.72	49	0.04	9.90	50			

COMPOUND: β-Naphthylamine

STRUCTURE:



FORMULA: $C_{10}H_9N$ **MOL. WT.** 143.19

FREUNDLICH PARAMETERS	pH		
	7.5		
K	150		
1/n	0.30		
Corr. Coef. r	0.94		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	300		
1.0	150		
0.1	75		
0.01	37		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	12	26	53
0.1		2.4	5.2
0.01			0.5

GRANULAR CARBON COLUMN

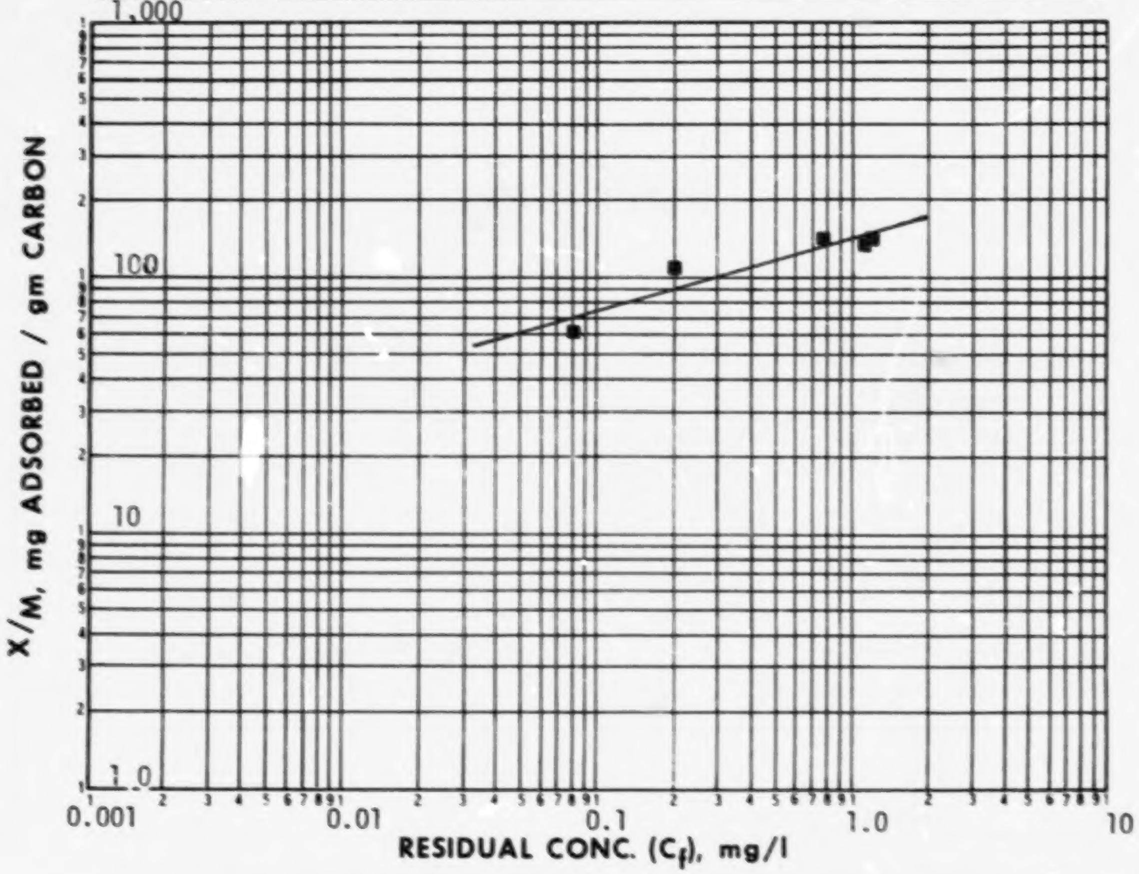
C_o, mg/l	
1.0	6.7
0.1	1.3
0.01	0.3

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 285 nm

REMARKS: OSHA regulated carcinogen.

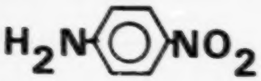
COMPOUND: β-Naphthylamine



	■ pH= 7.5			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	1.4								
1.1	1.24	0.16	151						
2.1	1.10	0.30	142						
4.1	0.78	0.62	152						
10.8	0.20	1.20	111						
21.7	0.08	1.32	61						

COMPOUND: ρ - Nitroaniline

STRUCTURE:



FORMULA: $C_6H_6N_2O_2$ **MOL. WT.** 138.13

FREUNDLICH PARAMETERS	pH		
	All data pooled		
K	140		
1/n	0.27		
Corr. Coef. r	0.98		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	250		
1.0	140		
0.1	74		
0.01	40		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	12	25	48
0.1		2.3	4.7
0.01			0.43

GRANULAR CARBON COLUMN

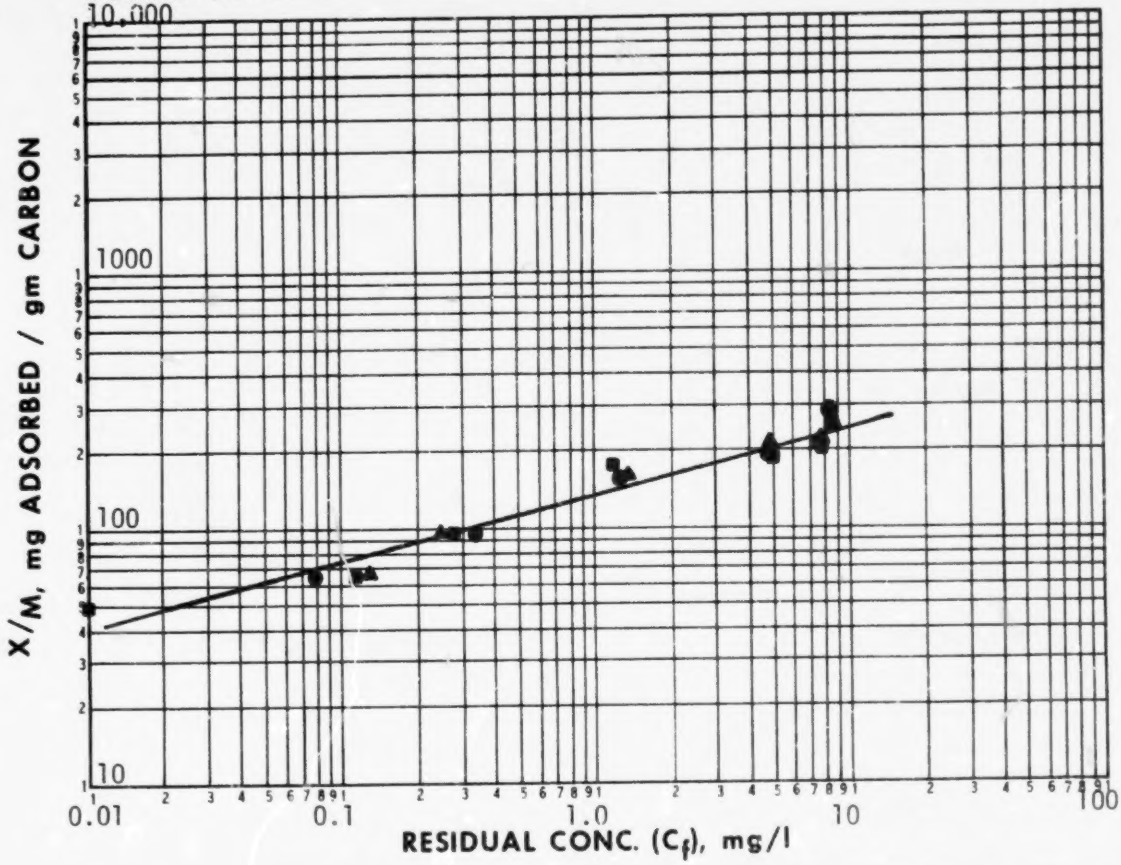
C_o, mg/l	
1.0	7.4
0.1	1.4
0.01	0.2

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Visible Spectroscopy 380 nm

REMARKS:

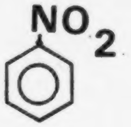
COMPOUND: ρ - Nitroaniline



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	9,84			9.89			10.0		
5	8.37	1.47	294	8.64	1.25	250	8.71	1.29	258
10	7.75	2.09	209	7.89	2.00	200	7.85	2.15	215
25	4.92	4.92	197	5.03	4.86	194	4.94	5.06	202
50	1.29	8.55	171	1.24	8.65	173	1.39	8.61	172
100	0.34	9.50	95	0.28	9.61	96	0.25	9.75	98
150	0.08	9.76	65	0.12	9.77	65	0.13	9.87	66
200				0.01	9.88	49	0.03	9.97	50

COMPOUND: Nitrobenzene

STRUCTURE:



FORMULA: $C_6H_5NO_2$ **MOL. WT.** 123.11

FREUNDLICH PARAMETERS	pH		
	7.5		
K	68		
1/n	0.43		
Corr. Coef. r	0.97		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	180		
1.0	68		
0.1	25		
0.01	9.3		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	36	110	290
0.1		9.6	28
0.01			2.6

GRANULAR CARBON COLUMN

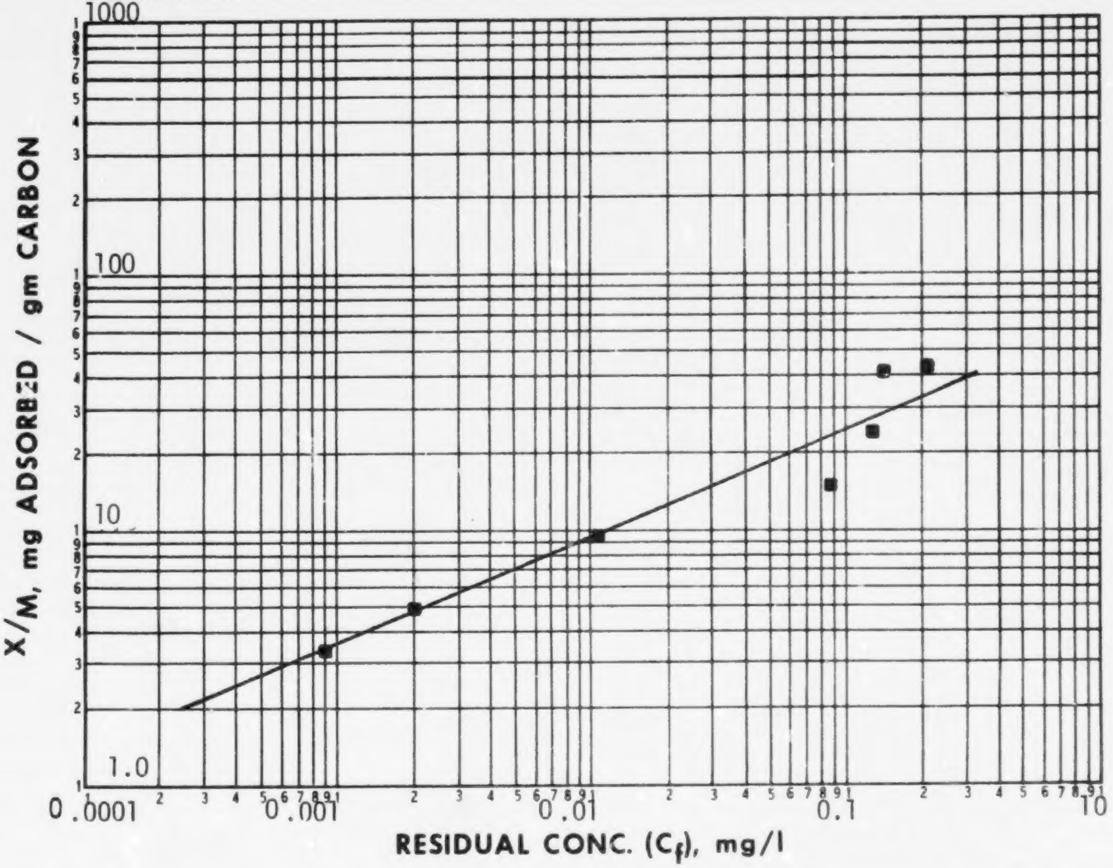
C_o, mg/l	
1.0	15
0.1	4.0
0.01	1.1

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent Extraction - G.C.

REMARKS:

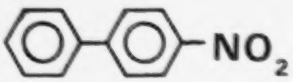
COMPOUND: Nitrobenzene



	■ pH= 7.5			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	0.250								
1	0.208	0.042	42.0						
2.5	0.149	0.101	40.4						
5	0.130	0.120	24.0						
10	0.089	0.162	16.2						
25	0.0115	0.239	9.54						
50	0.002	0.248	4.96						
75	0.0009	0.249	3.32						

COMPOUND: 4 - Nitrobiphenyl

STRUCTURE:



FORMULA: $C_{12}H_9NO_2$ **MOL. WT.** 199.21

FREUNDLICH PARAMETERS	pH		
	7.0		
K	370		
1/n	0.27		
Corr. Coef. r	0.98		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	690		
1.0	370		
0.1	200		
0.01	110		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	4.5	9.3	18
0.1		0.8	1.7
0.01			0.2

GRANULAR CARBON COLUMN

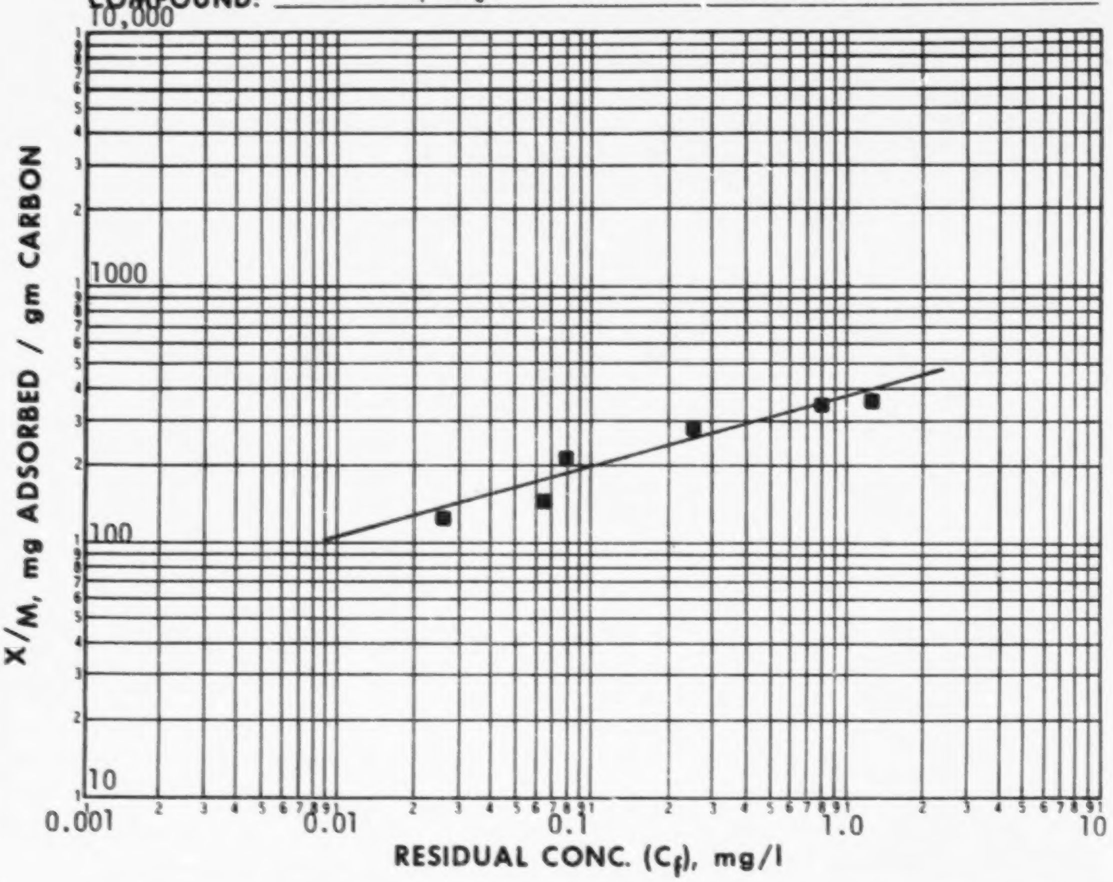
C_o, mg/l	
1.0	2.7
0.1	0.5
0.01	0.1

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 325 nm

REMARKS: OSHA regulated carcinogen

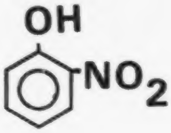
COMPOUND: 4-Nitrobiphenyl



	● pH= 7.0			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	1.670								
1.0	1.30	0.370	370						
2.5	0.800	0.870	348						
5.0	0.260	1.410	282						
7.5	0.082	1.588	212						
10.0	0.064	1.606	161						
12.5	0.027	1.643	131						

COMPOUND: 2-Nitrophenol

STRUCTURE:



FORMULA: $C_6H_5NO_3$ **MOL. WT.** 139.11

FREUNDLICH PARAMETERS	pH		
	3.0	5.5	9.0
K	101	99	85
1/n	0.26	0.34	0.39
Corr. Coef. r	0.99	0.97	0.97
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	101	99	85
0.1	56	46	35
0.01	31	21	14
0.001	17	9.6	5.7

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	20	47	100
0.1		4.3	10
0.01			1.0

GRANULAR CARBON COLUMN

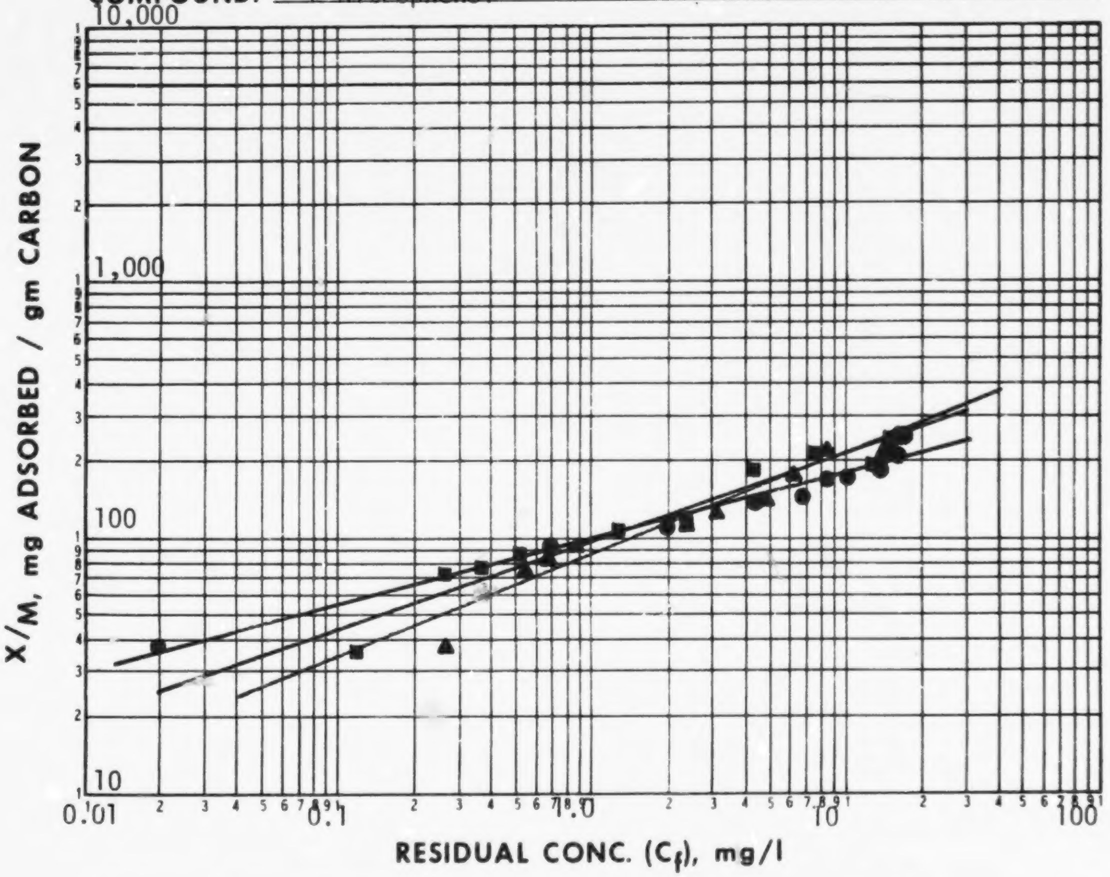
C_o, mg/l	
1.0	10
0.1	2.2
0.01	0.5

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 278.6 nm

REMARKS:

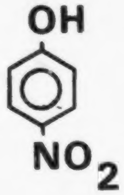
COMPOUND: 2-Nitrophenol



	● pH= 3.0			■ pH= 5.5			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	19.03			18.20			19.51		
5	17.74	1.29	258						
10	17.00	2.03	203	15.74	2.46	246	16.93	2.58	258
15	15.79	3.24	216						
25	14.33	4.70	188	13.29	4.91	196	14.18	5.33	213
50	10.09	8.94	179	7.28	10.92	218	8.36	11.15	223
60	8.59	10.44	174						
75	6.95	12.08	161	4.26	13.94	186	6.13	13.38	178
100	4.34	14.69	147	3.84	14.36	144	4.89	14.62	146
125				2.35	15.85	127	3.13	16.38	131
150	2.00	17.03	114	1.31	16.89	113	2.34	17.17	114
200	0.70	18.33	92	0.51	17.69	88	0.87	18.64	93
225				0.37	17.83	79	0.68	18.83	84
250				0.27	17.93	72	0.53	18.98	76
500	0.02	19.01	38	0.12	18.08	36	0.27	19.24	38

COMPOUND: 4-Nitrophenol

STRUCTURE:



FORMULA: $C_6H_5NO_3$ **MOL. WT.** 139.11

FREUNDLICH PARAMETERS	pH		
	3.0	5.4	9.0
K	80.2	76.2	71.2
1/n	0.17	0.25	0.28
Corr. Coef. r	0.86	0.92	0.93
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	80	76	71
0.1	54	43	38
0.01	37	24	20
0.001	25	14	11

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	21	41	74
0.1		3.7	7.3
0.01			0.7

GRANULAR CARBON COLUMN

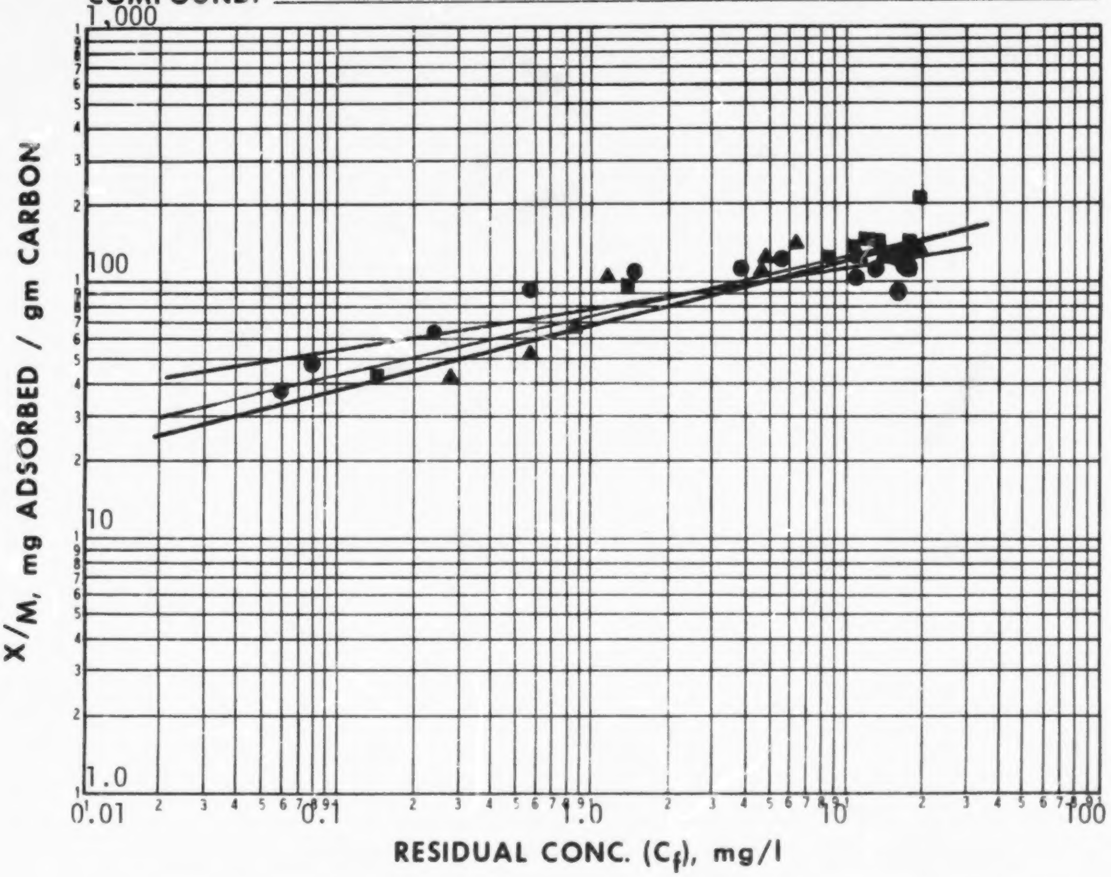
C_o, mg/l	
1.0	13
0.1	2.3
0.01	0.4

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 316.8 nm

REMARKS:

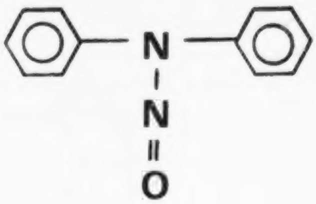
COMPOUND: 4-Nitrophenol



	● pH= 3.0			■ pH= 5.4			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	19.16			21.34			21.29		
10	17.92	1.24	124	19.25	2.09	209	19.84	1.45	145
20				18.33	3.01	150			
25	16.90	2.26	90	18.27	3.07	123	17.82	3.47	139
30				17.35	3.99	133			
40				16.03	5.31	133			
50	13.17	5.99	120	13.41	7.93	159	14.51	6.78	136
60				11.60	9.74	162			
75	11.20	7.96	106	10.41	10.93	146	11.39	9.90	132
100	5.75	13.41	134	8.31	13.03	130	6.25	15.04	150
125	3.97	15.19	122				4.86	16.43	131
150	1.58	17.58	117				4.60	16.69	111
200	0.58	18.58	93	1.44	19.90	99	1.18	20.11	101
300	0.24	18.92	63				0.84	20.45	68
400	0.08	19.08	48				0.57	20.72	52
500	0.06	19.10	38	0.15	21.19	42	0.28	21.01	42

COMPOUND: N - Nitrosodiphenylamine

STRUCTURE:



FORMULA: $C_{12}H_{10}N_2O$ **MOL. WT.** 198.07

FREUNDLICH PARAMETERS	pH		
	All data pooled		
K	220		
1/n	0.37		
Corr. Coef. r	0.98		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	510		
1.0	220		
0.1	91		
0.01	38		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	9.8	25	60
0.1		2.3	5.9
0.01			0.54

GRANULAR CARBON COLUMN

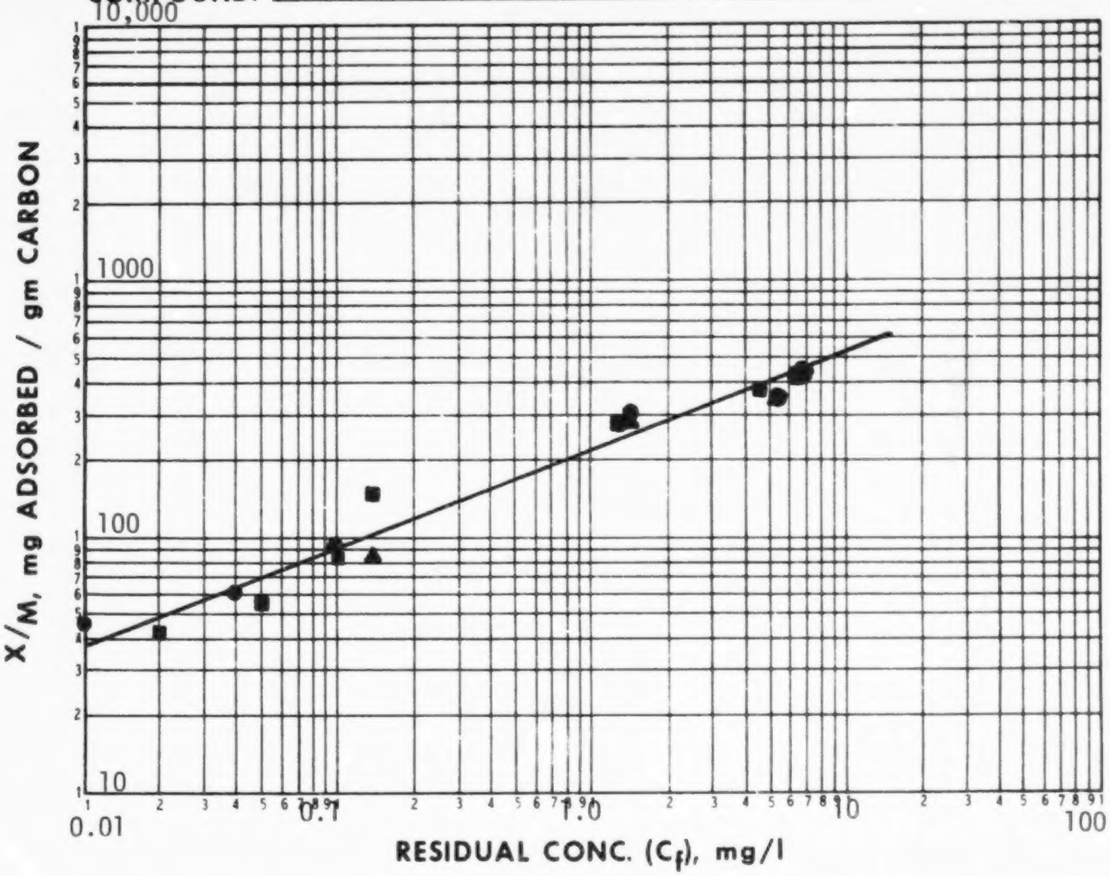
C_o, mg/l	
1.0	4.6
0.1	1.1
0.01	0.3

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 290 nm

REMARKS:

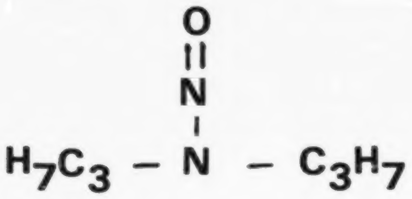
COMPOUND: N - Nitrosodiphenylamine



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	9.18			8.36			8.70		
5	6.99	2.19	438	6.23	2.13	426	6.64	2.06	412
10	5.60	3.58	358	4.60	3.76	376	5.15	3.55	355
25	1.62	7.56	302	1.29	7.07	282	1.45	7.25	290
50				0.14	8.22	164			
100	0.10	9.08	91	0.10	8.26	83	0.14	8.56	86
150	0.04	9.14	61	0.05	8.31	55			
200	0.01	9.17	46	0.02	8.34	42			

COMPOUND: N-Nitrosodi-n-propylamine

STRUCTURE:



$$H_7C_3 - \overset{\overset{\displaystyle O}{\|}}{\underset{|}{N}}\!\!\!\!\!\!\!\!\!\!\!\overset{}{}\;\; - N - C_3H_7$$

FORMULA: $C_6H_{14}N_2O$ **MOL. WT.** 130.19

FREUNDLICH PARAMETERS	pH		
	All Data Pooled		
K	24.4		
1/n	0.26		
Corr. Coef. r	0.87		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	24		
0.1	13		
0.01	7.4		
0.001	4.0		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	67	130	250
0.1		12	24
0.01			2.2

GRANULAR CARBON COLUMN

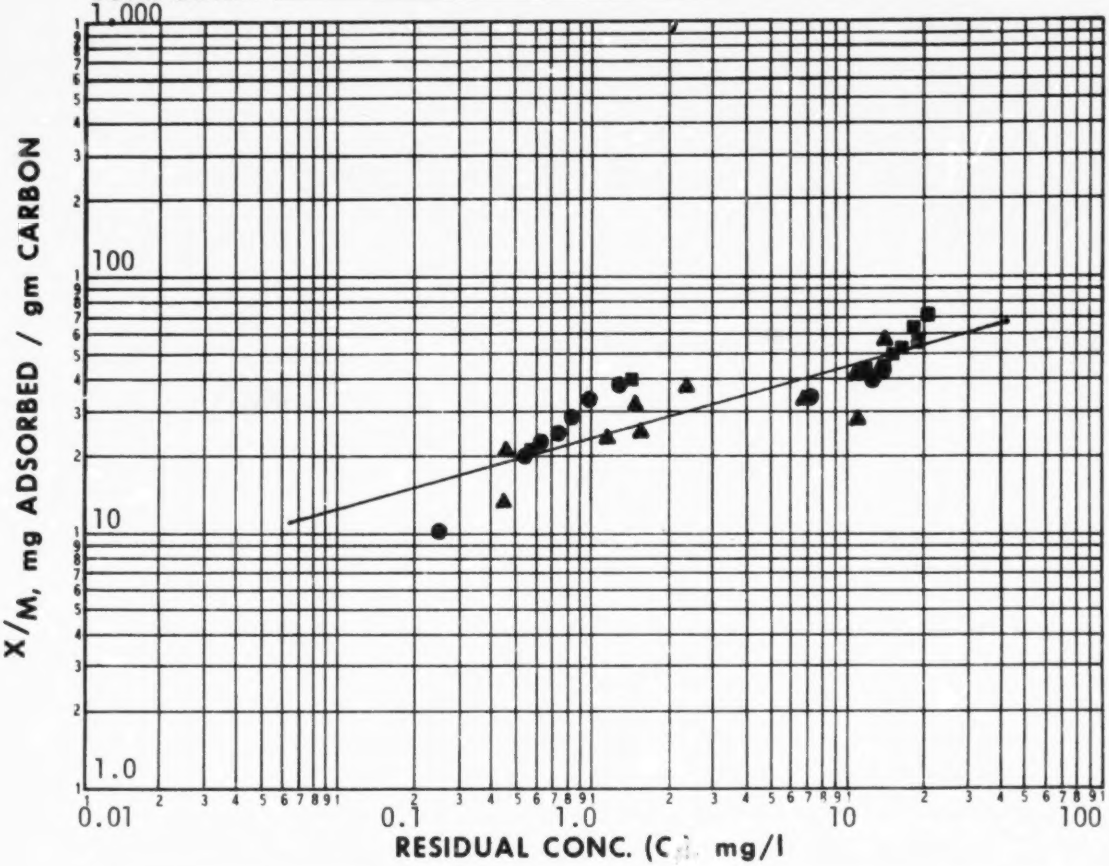
C_o, mg/l	
1.0	42
0.1	7.7
0.01	1.4

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 232.4 nm

REMARKS:

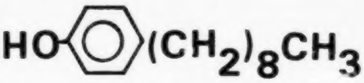
COMPOUND: N-Nitrosodi-n-propylamine



pH 3 & 5.3	pH 9	● pH= 3.0			■ pH= 5.3			▲ pH= 9.0		
CARBON DOSE mg/l		C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	0	20.83			21.25			16.74		
10					20.53	0.72	72.0			
25	38.5				19.83	1.42	56.8	14.47	2.27	59.0
50					18.06	3.19	63.8			
75	96.2				17.35	3.90	52.0	12.88	3.86	40.1
100					16.25	5.00	50.0			
125	135				14.90	6.35	50.8	11.22	5.52	40.9
150		14.40	6.43	42.9	14.44	6.81	45.4			
200	192	12.75	8.08	40.4	12.30	8.95	44.8	11.09	5.65	29.4
400		7.21	13.62	34.0						
500	288	1.31	19.52	39.0	1.48	19.77	39.5	6.84	9.90	34.4
600	385	1.03	19.80	33.0				2.30	14.44	37.5
700	480	0.85	19.98	28.5				1.60	15.14	31.5
800	577	0.75	20.08	25.1				1.66	15.08	26.1
900	673	0.62	20.21	22.5				1.18	15.56	23.1
1000	769	0.55	20.28	20.3	0.58	20.67	20.07	0.47	16.27	21.1
2000	1150	0.26	20.57	10.3				0.44	16.30	14.1

COMPOUND: p - Nonylphenol

STRUCTURE:



FORMULA: $C_{15}H_{24}O$ **MOL. WT.** 220.34

FREUNDLICH PARAMETERS	pH		
	3.0	7.0	9.0
K	53	250	150
1/n	1.04	0.37	0.27
Corr. Coef. r	0.97	0.99	0.98
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	580	600	280
1.0	53	250	150
0.1	4.8	110	80
0.01	0.44	46	43

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	8.3	21	51
0.1		2.0	5.0
0.01			0.5

GRANULAR CARBON COLUMN

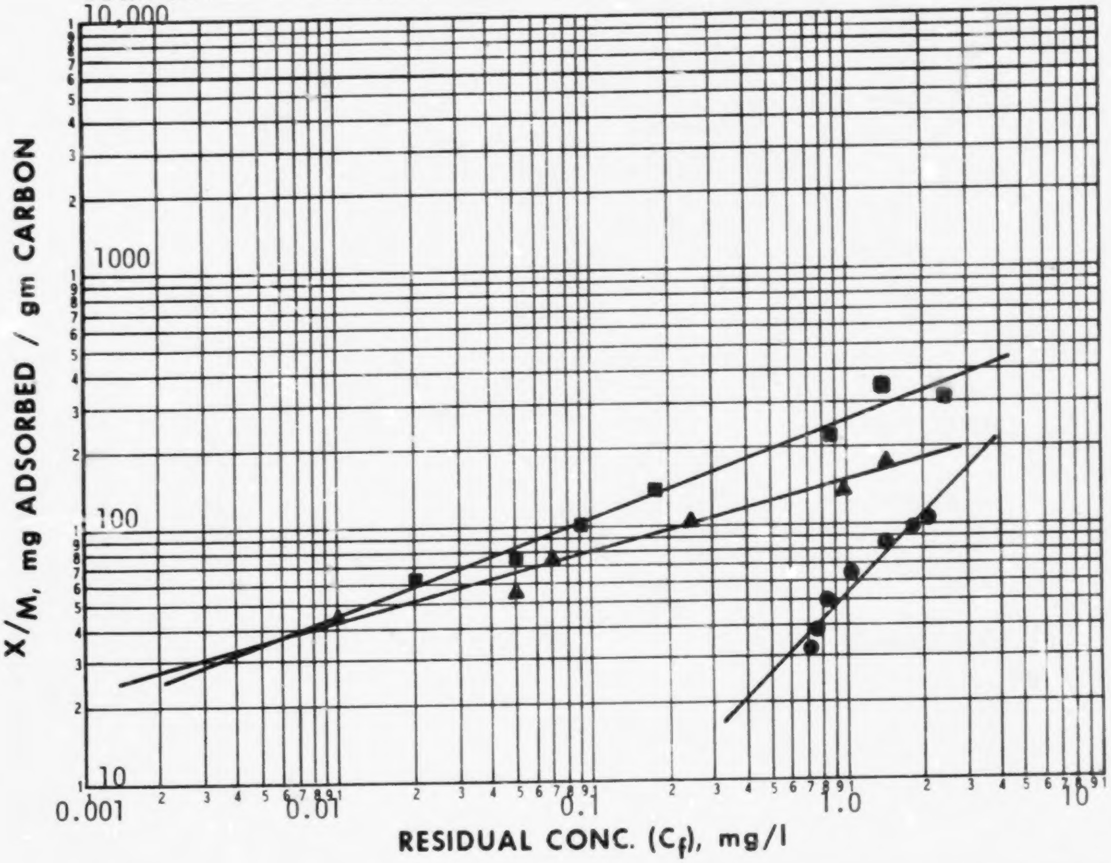
C_o, mg/l	
1.0	3.9
0.1	0.9
0.01	0.2

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 237 nm. All samples adjusted to pH 12 for U.V. measurement.

REMARKS:

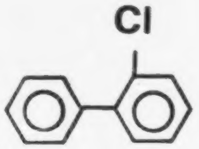
COMPOUND: P - Nonylphenol

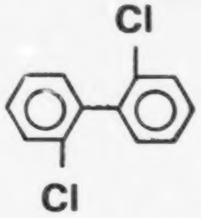


	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	**C_f**	**$C_o - C_f = X$**	**X/M**	**C_f**	**$C_o - C_f = X$**	**X/M**	**C_f**	**$C_o - C_f = X$**	**X/M**
0	2.34			3.13			2.35		
2.5	2.08	0.26	104	2.36	0.77	308			
5	1.85	0.49	98	1.39	1.74	348	1.46	0.89	178
10	1.50	0.84	84	0.88	2.25	225	0.99	1.36	136
20	1.06	1.28	64	0.18	2.95	148	0.24	2.11	106
30	0.85	1.49	50	0.09	3.04	101	0.07	2.28	76
40	0.78	1.56	39	0.05	3.08	77	0.05	2.30	57
50	0.72	1.62	32	0.02	3.11	62	0.01	2.34	46

COMPOUND: PCB 1221

STRUCTURE:





1221

FORMULA: $C_{12}H_9Cl$ - 51%
$C_{12}H_8Cl_2$ 32%
$C_{12}H_{10}$ 11%

MOL. WT. ~ 200.7

FREUNDLICH PARAMETERS	pH		
	5.3		
K	242		
1/n	0.70		
Corr. Coef. r	0.99		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	242		
0.1	48		
0.01	9.5		
0.001	1.9		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON
C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	19	100	520
0.1		9.3	52
0.01			5.7

GRANULAR CARBON COLUMN

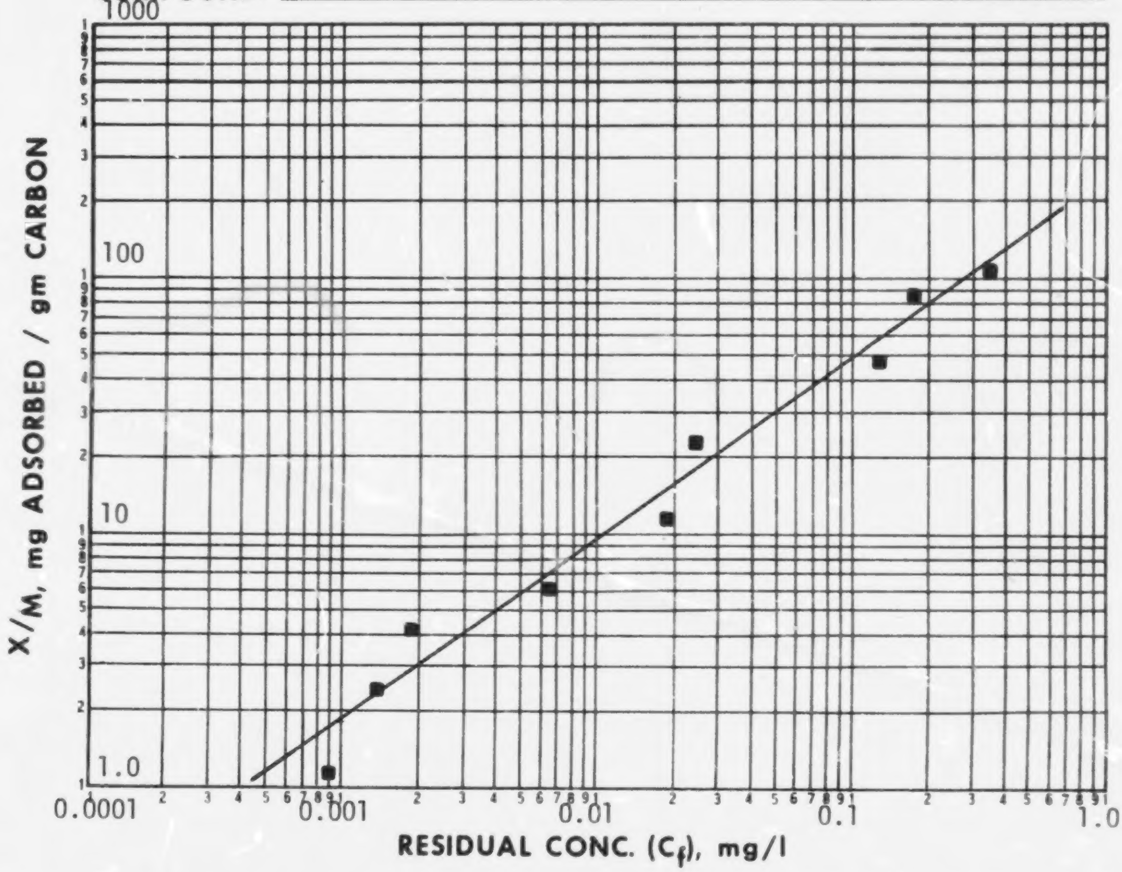
C_o, mg/l	
1.0	4.1
0.1	2.1
0.01	1.1

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent extraction - G.C.

REMARKS: Structures shown are for major components.

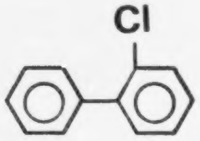
COMPOUND: PCB 1221

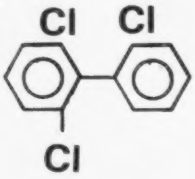


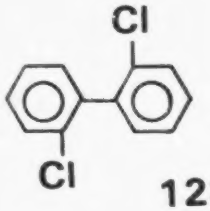
	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	0.611								
2.5	0.341	0.270	108						
5	0.181	0.430	86.0						
10	0.127	0.484	48.4						
25	0.024	0.587	23.5						
50	0.019	0.592	11.8						
100	0.006	0.605	6.05						
150	0.002	0.609	4.06						
250	0.001	0.610	2.44						
500	0.001	0.610	1.22						

COMPOUND: PCB-1232

STRUCTURE:







1232

$C_{12}H_9Cl$ 31%

$C_{12}H_7Cl_3$ 28%

FORMULA: $C_{12}H_8Cl_2$ 24%

MOL. WT. ~ 232.2

FREUNDLICH PARAMETERS	pH		
K	630		
1/n	0.73		
Corr. Coef. r	0.98		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	630		
0.1	120		
0.01	22		
0.001	4.0		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	7.7	45	240
0.1		4.1	24
0.01			2.2

GRANULAR CARBON COLUMN

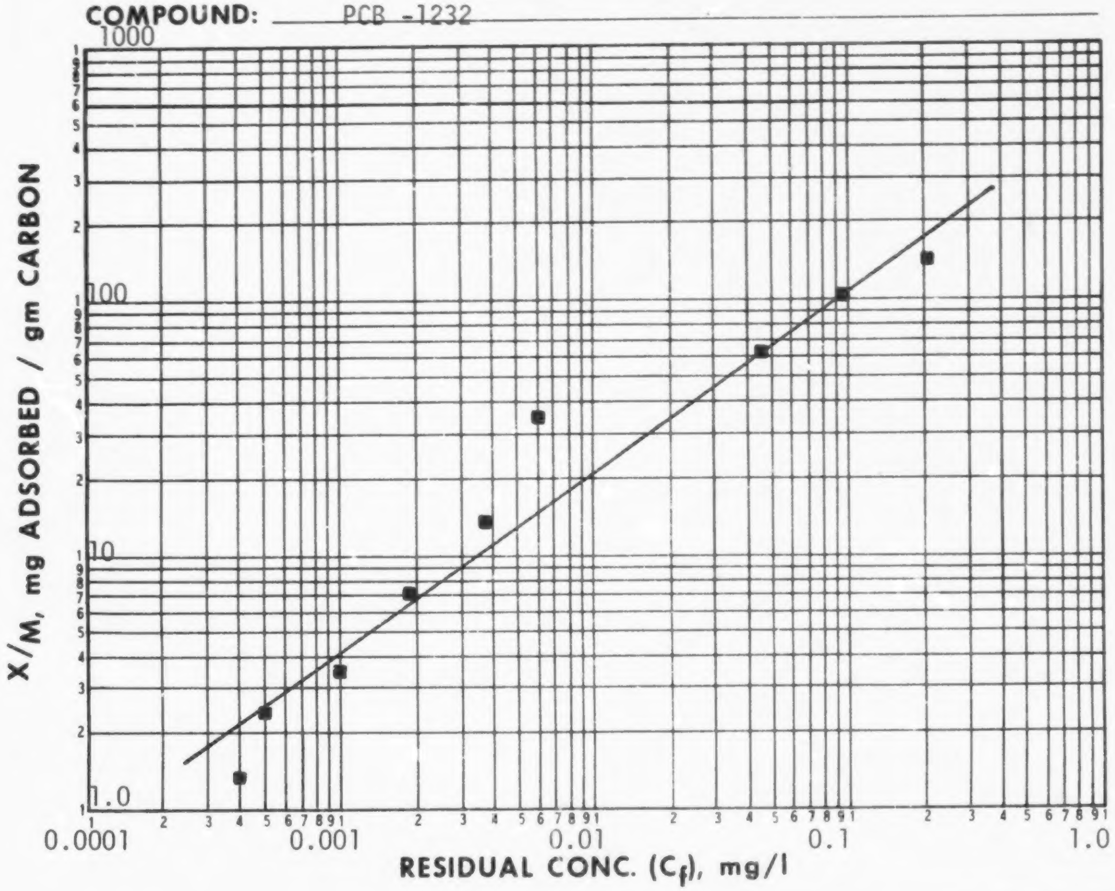
C_o, mg/l	
1.0	1.6
0.1	0.8
0.01	0.5

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent - extraction - G.C.

REMARKS: Structures shown are for major components.

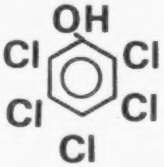
COMPOUND: PCB -1232



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	0.353								
1.0	0.206	0.147	147						
2.5	0.096	0.257	103						
5	0.046	0.307	61.4						
10	0.006	0.347	34.7						
25	0.004	0.349	13.9						
50	0.002	0.351	7.02						
100	0.001	0.352	3.52						
150	0.0005	0.352	2.35						
250	0.0004	0.353	1.41						
500	0.0001	0.353	0.71						

COMPOUND: Pentachlorophenol

STRUCTURE:



FORMULA: C_6HOCl_5 **MOL. WT.** 266.4

FREUNDLICH PARAMETERS	pH		
	3.0	7.0	9.0
K	260	150	100
1/n	0.39	0.42	0.41
Corr. Coef. r	0.98	0.98	0.98
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	630	380	260
1.0	260	150	100
0.1	110	55	39
0.01	44	21	15

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	16	47	130
0.1		4.3	12
0.01			1.1

GRANULAR CARBON COLUMN

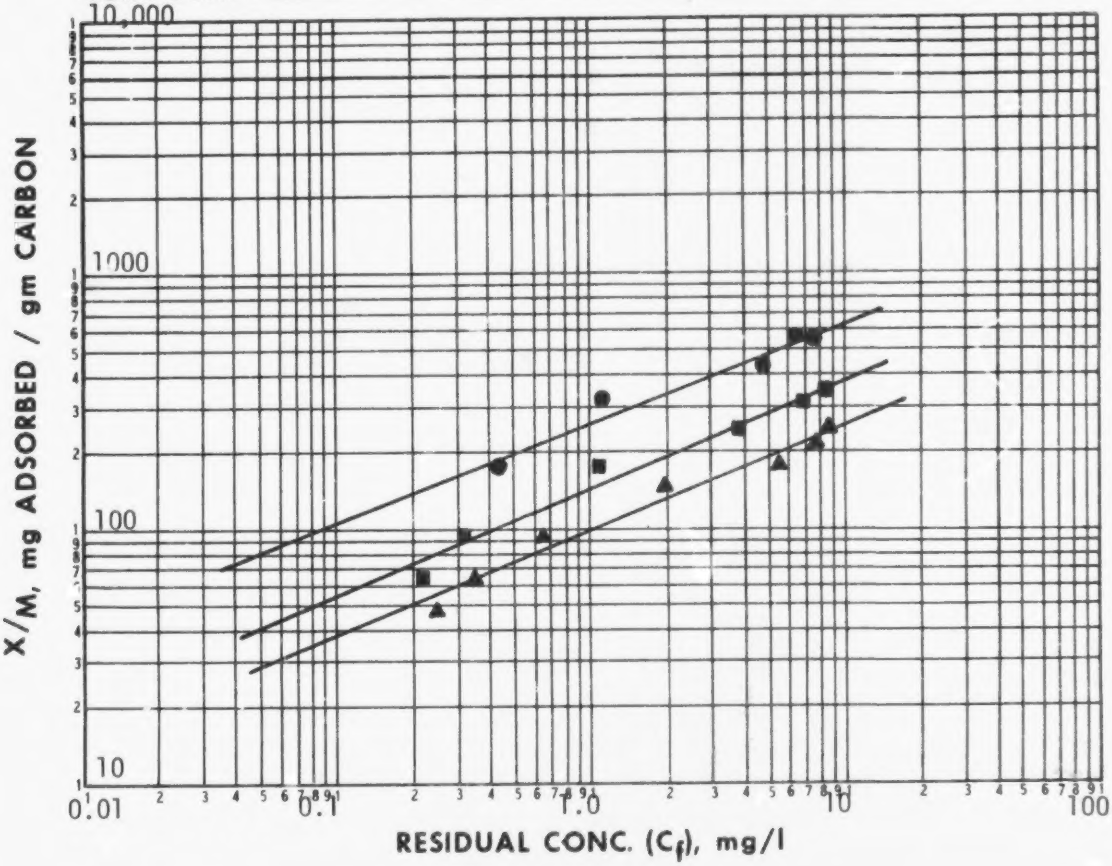
C_o, mg/l	
1.0	6.9
0.1	1.8
0.01	0.5

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 247 nm, basic pH

REMARKS:

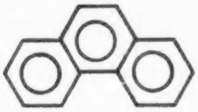
COMPOUND: Pentachlorophenol



		● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l		**C_f**	**$C_o-C_f=X$**	**X/M**	**C_f**	**$C_o-C_f=X$**	**X/M**	**C_f**	**$C_o-C_f=X$**	**X/M**
pH 3 only	pH 7 pH 9									
0	0	9.23			9.23			9.95		
2.5	5	7.82	1.41	564	8.18	1.75	350	8.70	1.25	250
5	10	6.37	2.86	572	6.85	3.08	308	7.79	2.16	216
10	25	4.90	4.33	433	3.77	6.16	246	5.42	4.53	181
25	50	1.20	8.03	321	1.09	8.84	177	1.95	8.00	160
50	100	0.44	8.79	176	0.31	9.62	96	0.63	9.32	93
100	150				0.22	9.71	65	0.34	9.61	64
150	200							0.24	9.71	49

COMPOUND: Phenanthrene

STRUCTURE:



FORMULA: $C_{14}H_{10}$ **MOL. WT.** 178.24

FREUNDLICH PARAMETERS	pH		
	5.3		
K	215		
1/n	0.44		
Corr. Coef. r	0.98		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	215		
0.1	78		
0.01	29		
0.001	10		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	11	34	95
0.1		3.1	9.4
0.01			0.9

GRANULAR CARBON COLUMN

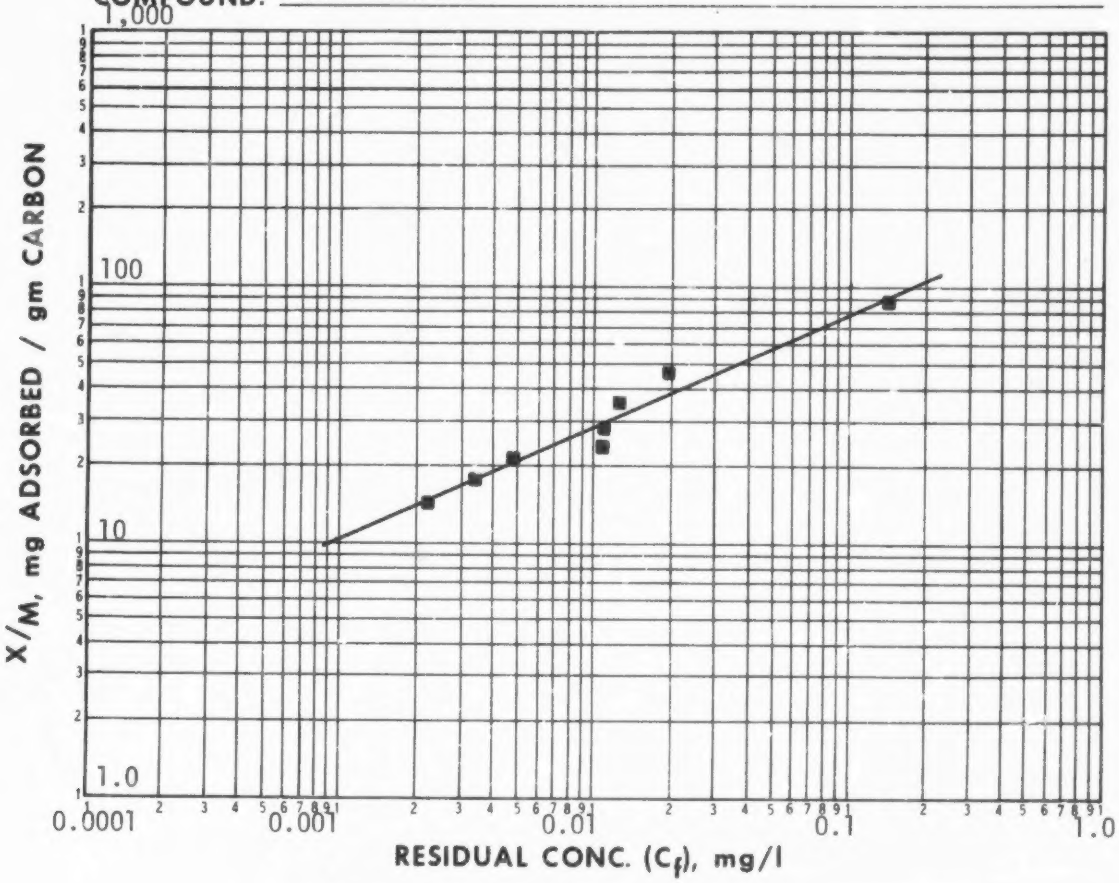
C_o, mg/l	
1.0	4.7
0.1	1.3
0.01	0.3

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Solvent Extraction - G.C.

REMARKS:

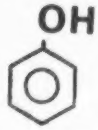
COMPOUND: Phenanthrene



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	0.370								
2.5	0.147	0.223	89.2						
7.5	0.196	0.350	46.7						
10	0.0133	0.357	35.7						
12.5	0.0112	0.359	28.7						
15	0.0108	0.359	23.9						
17.5	0.0049	0.365	20.9						
20	0.0033	0.367	18.3						
25	0.0022	0.368	14.7						

COMPOUND: Phenol

STRUCTURE:



FORMULA: C_6H_6O **MOL. WT.** 94.11

FREUNDLICH PARAMETERS	pH		
	All data pooled		
K	21		
1/n	0.54		
Corr. Coef. r	0.89		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	74		
1.0	21		
0.1	6.0		
0.01	1.7		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	150	570	2,000
0.1		52	200
0.01			18

GRANULAR CARBON COLUMN

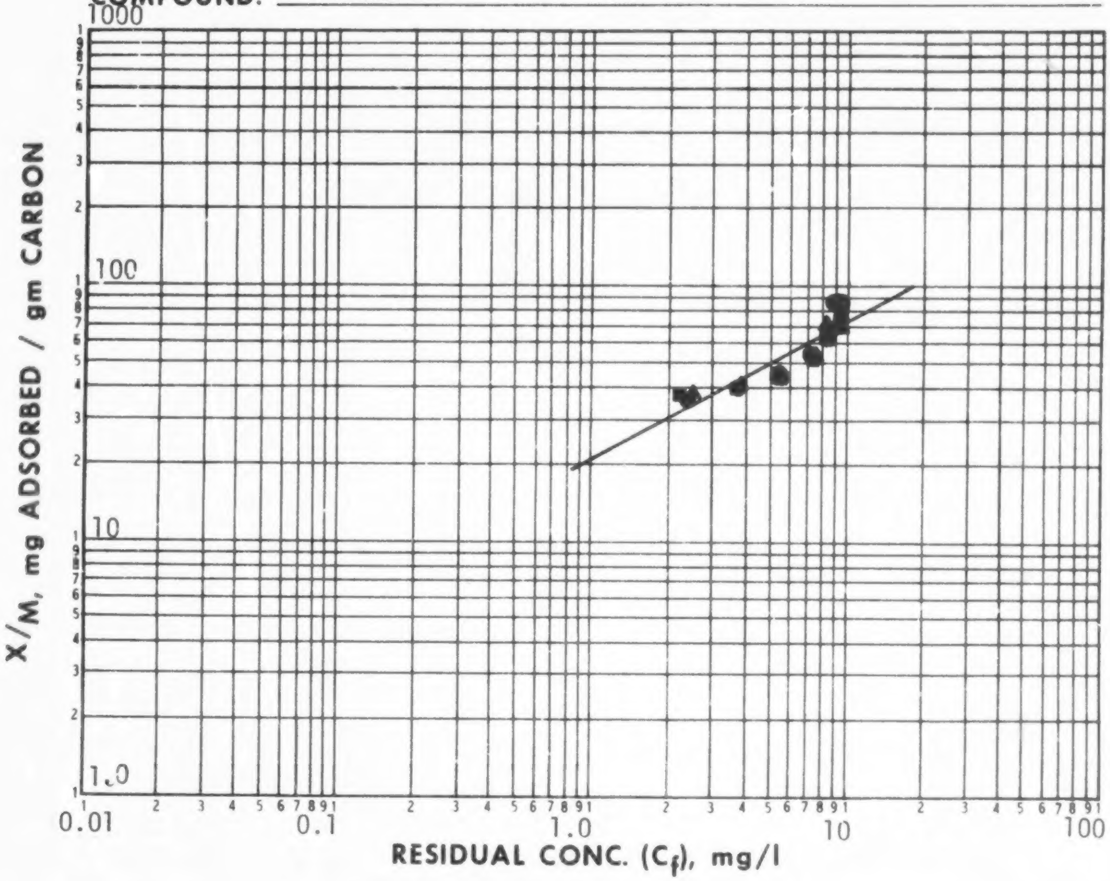
C_o, mg/l	
1.0	47
0.1	17
0.01	5.8

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 288 nm

REMARKS:

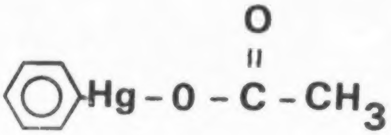
COMPOUND: Phenol



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	9.84			9.80			9.96		
5	9.40	0.44	88	9.36	0.44	88			
10	8.96	0.88	88	9.06	0.74	74	9.26	0.70	70
25	8.27	1.57	63	8.24	1.56	62	8.17	1.79	72
50	7.12	2.72	54	7.24	2.56	51	7.26	2.70	54
100	5.27	4.57	46	5.36	4.44	44	5.27	4.69	47
150	3.80	6.04	40	3.74	6.06	40	3.75	6.21	41
200	2.35	7.49	37	2.15	7.65	38	2.45	7.51	38

COMPOUND: Phenylmercuric acetate

STRUCTURE:



FORMULA: $C_8H_8HgO_2$ **MOL. WT.** 336.74

FREUNDLICH PARAMETERS	pH		
	3.0 and 7.0 pooled	9.0	
K	270	130	
1/n	0.44	0.54	
Corr. Coef. r	0.99	0.99	
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	740	440	
1.0	270	130	
0.1	97	37	
0.01	35	11	

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	9.2	28	77
0.1		2.5	7.7
0.01			0.70

GRANULAR CARBON COLUMN

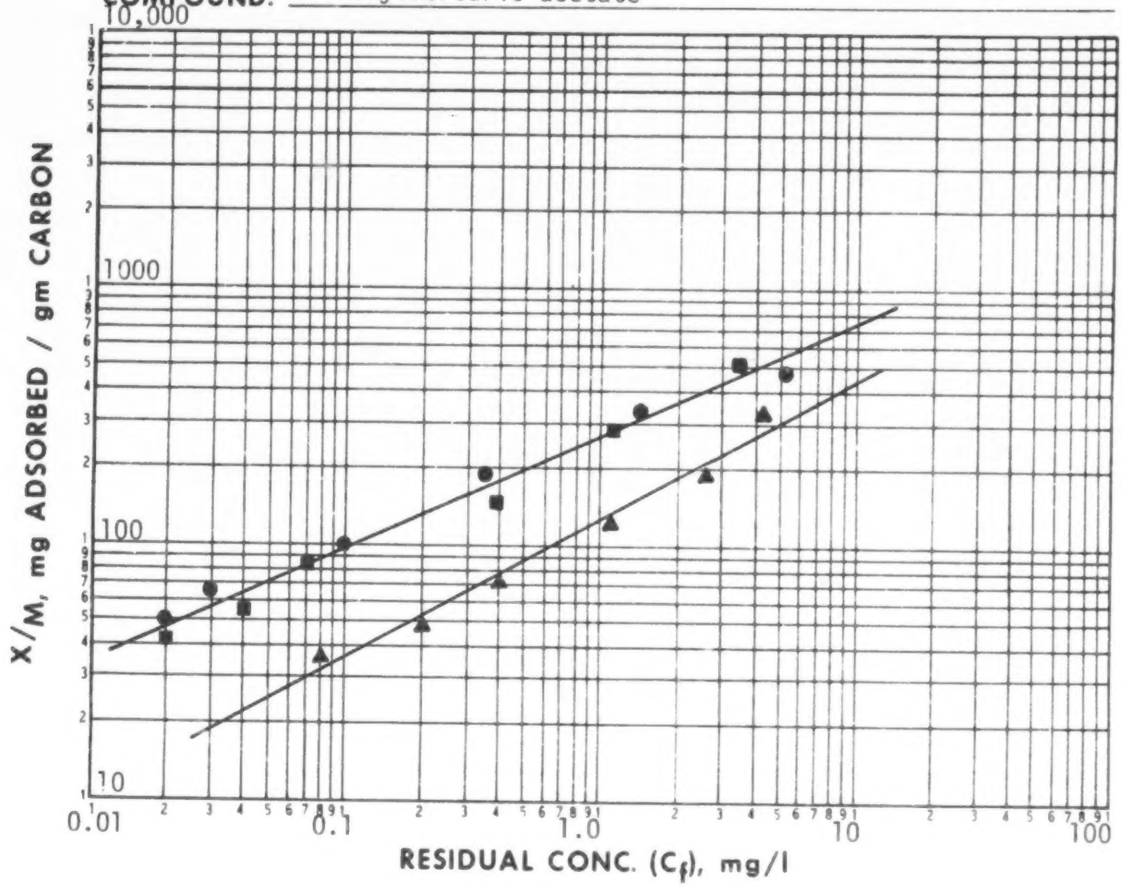
C_o, mg/l	
1.0	3.7
0.1	1.0
0.01	0.3

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Atomic Adsorption: Hg

REMARKS:

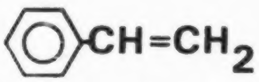
COMPOUND: Phenylmercuric acetate



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	10.1			8.39			7.55		
10	5.20	4.90	490	3.36	5.03	503	4.20	3.35	335
25	1.61	8.49	340	1.18	7.21	288	2.69	4.86	194
50	0.37	9.73	195	0.39	8.00	160	1.14	6.41	128
100	0.10	10.00	100	0.07	8.32	83.2	0.40	7.15	71.5
150	0.03	10.07	67	0.04	8.35	55.6	0.20	7.35	49
200	0.02	10.08	50	0.02	8.37	41.9	0.08	7.47	37.4

COMPOUND: Styrene

STRUCTURE:



FORMULA: C_8H_8 **MOL. WT.** 104.14

FREUNDLICH PARAMETERS	pH		
	All data pooled		
K	120		
1/n	0.56		
Corr. Coef. r	0.98		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	440		
1.0	120		
0.1	33		
0.01	9.0		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	27	110	400
0.1		9.8	39
0.01			3.6

GRANULAR CARBON COLUMN

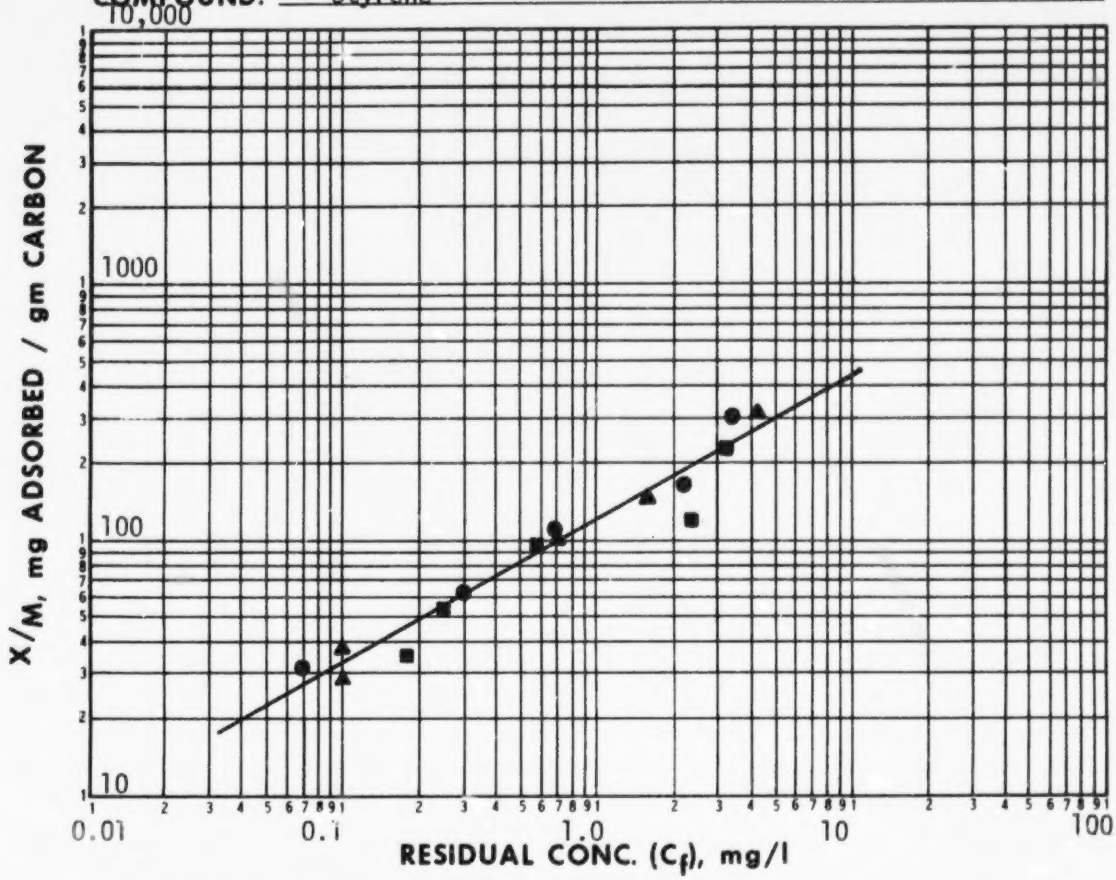
C_o, mg/l	
1.0	8.3
0.1	3.0
0.01	1.1

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 245 nm

REMARKS:

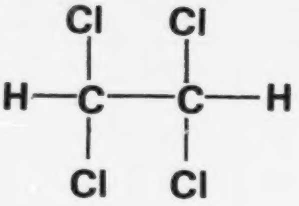
COMPOUND: Styrene



	● pH= 3.0			■ pH=7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	6.45			5.50			5.75		
5							4.17	1.58	316
10	3.43	3.02	302	3.20	2.30	230			
25	2.25	4.20	168	2.30	3.20	128	1.70	4.05	162
50	0.70	5.75	115	0.58	4.92	98	0.70	5.05	101
100	0.30	6.15	62	0.25	5.25	53			
150				0.18	5.32	36	0.10	5.65	38
200	0.07	6.38	31				0.10	5.65	29

COMPOUND: 1,1,2,2-Tetrachloroethane

STRUCTURE:



FORMULA: $C_2H_2Cl_4$ **MOL. WT.** 167.85

FREUNDLICH PARAMETERS	pH		
	5.3		
K	10.6		
1/n	0.37		
Corr. Coef. r	0.96		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	11		
0.1	4.5		
0.01	1.9		
0.001	0.8		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.1	0.001
1.0	360	940	2200
0.1		90	220
0.01			20

GRANULAR CARBON COLUMN

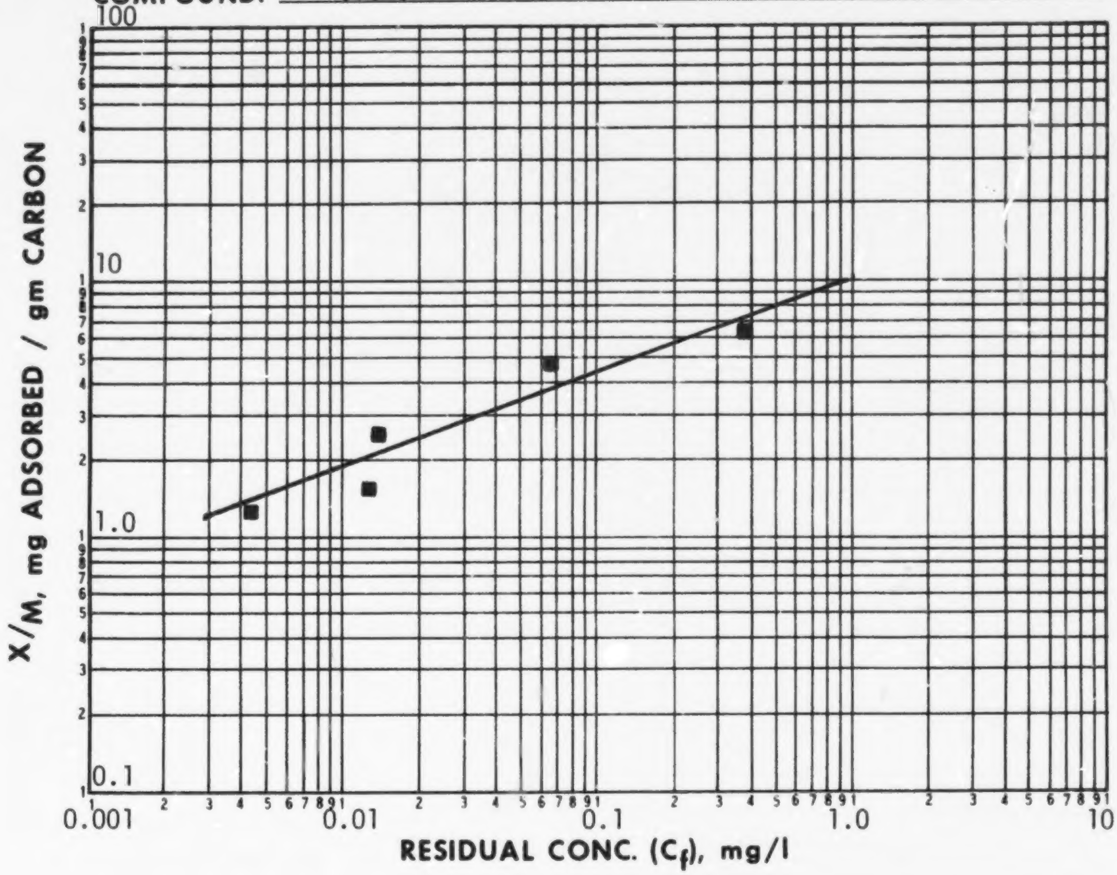
C_o, mg/l	
1.0	95
0.1	22
0.01	5.3

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G.C. Purge and Trap

REMARKS:

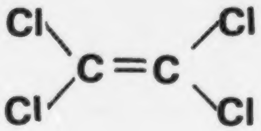
COMPOUND: 1,1,2,2-Tetrachloroethane



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	1.000								
96	0.382	0.618	6.42						
192	0.065	0.935	4.86						
385	0.014	0.986	2.56						
580	0.013	0.987	1.70						
769	0.0042	0.9958	1.30						

COMPOUND: Tetrachloroethene (Tetrachloroethylene)

STRUCTURE:



FORMULA: C_2Cl_4 **MOL. WT.** 165.83

FREUNDLICH PARAMETERS	pH		
	5.3		
K	50.8		
1/n	0.56		
Corr. Coef. r	0.96		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	51		
0.1	14.0		
0.01	3.9		
0.001	1.1		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	64	260	940
0.1		23	93
0.01			8.5

GRANULAR CARBON COLUMN

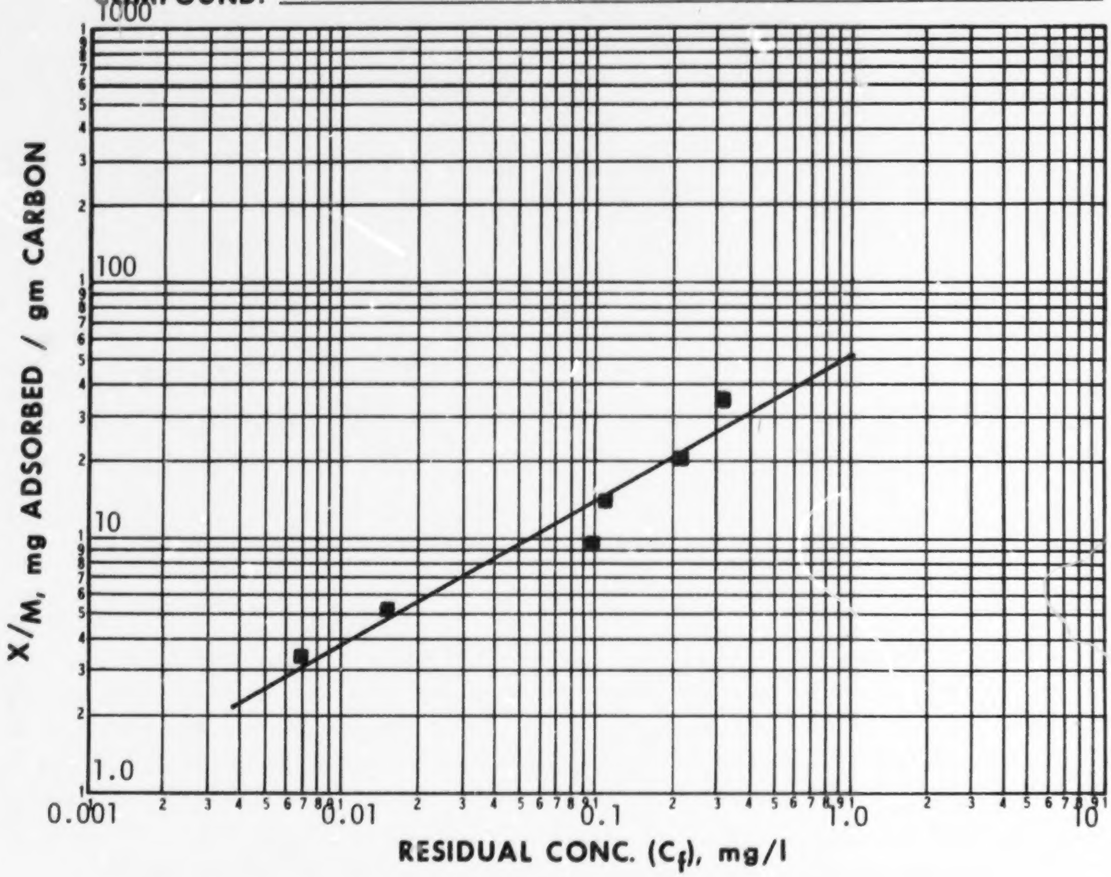
C_o, mg/l	
1.0	20
0.1	7.1
0.01	2.6

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G.C. Purge and Trap

REMARKS:

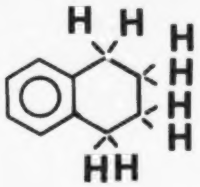
COMPOUND: Tetrachloroethene (Tetrachloroethylene)



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	1.000								
19	0.313	0.687	35.8						
38	0.213	0.787	20.4						
58	0.114	0.886	15.4						
96	0.100	0.900	9.36						
192	0.016	0.984	5.12						
288	0.007	0.993	3.44						

COMPOUND: 1,2,3,4 - Tetrahydronaphthalene

STRUCTURE:



FORMULA: $C_{10}H_{12}$ **MOL. WT.** 132.21

FREUNDLICH PARAMETERS	pH		
	7.4		
K	74		
1/n	0.81		
Corr. Coef. r	0.97		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	480		
1.0	74		
0.1	11		
0.01	1.7		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	78	560	3,600
0.1		51	360
0.01			33

GRANULAR CARBON COLUMN

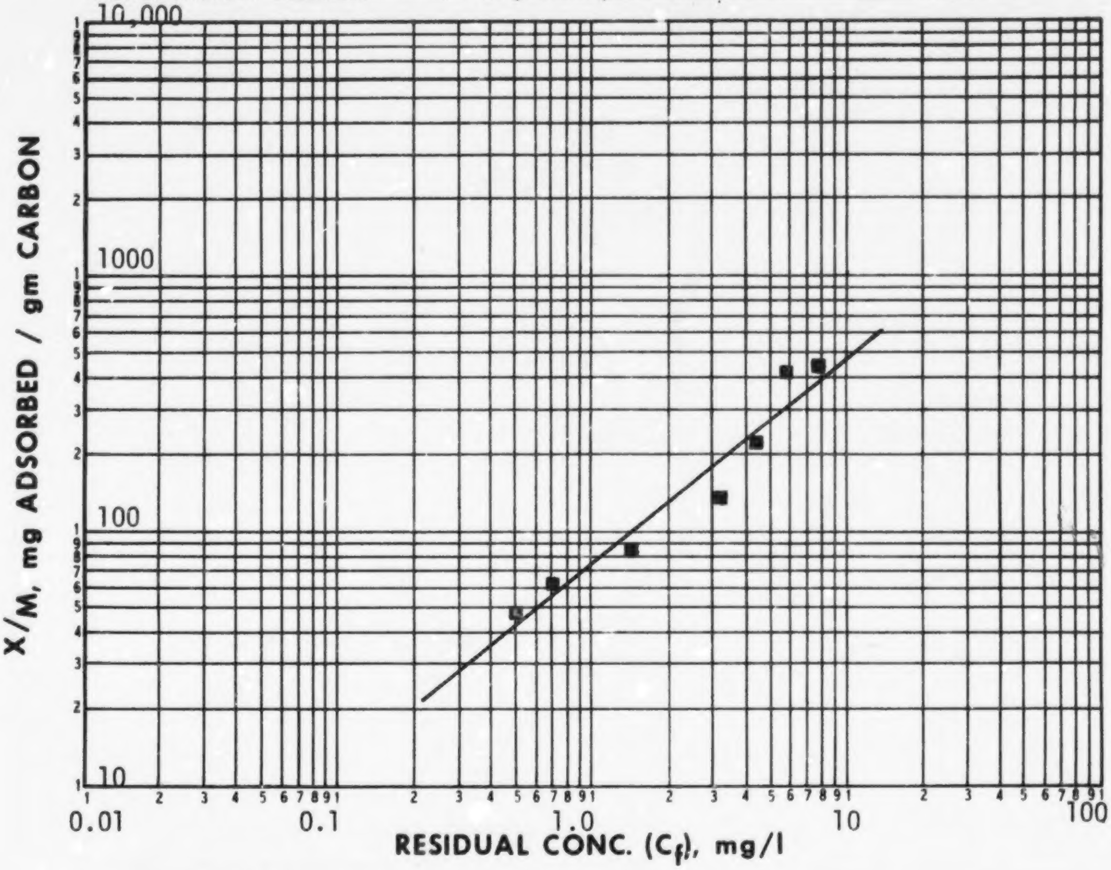
C_o, mg/l	
1.0	14
0.1	8.8
0.01	5.7

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 264 nm

REMARKS:

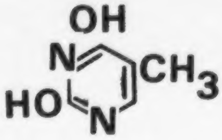
COMPOUND: 1,2,3,4 - Tetrahydronaphthalene



	■ pH= 7.36			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	10.00								
5	7.8	2.20	440						
10	5.9	4.10	410						
25	4.3	5.70	228						
50	3.2	6.80	136						
100	1.5	8.50	85						
150	0.70	9.30	62						
200	0.50	9.50	47.5						

COMPOUND: Thymine

STRUCTURE:



FORMULA: $C_5H_6N_2O_2$ **MOL. WT.** 126.11

FREUNDLICH PARAMETERS	pH		
	All data pooled		
K	27		
1/n	0.51		
Corr. Coef. r	0.91		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	89		
1.0	27		
0.1	8.5		
0.01	2.6		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	110	380	1200
0.1		34	120
0.01			11

GRANULAR CARBON COLUMN

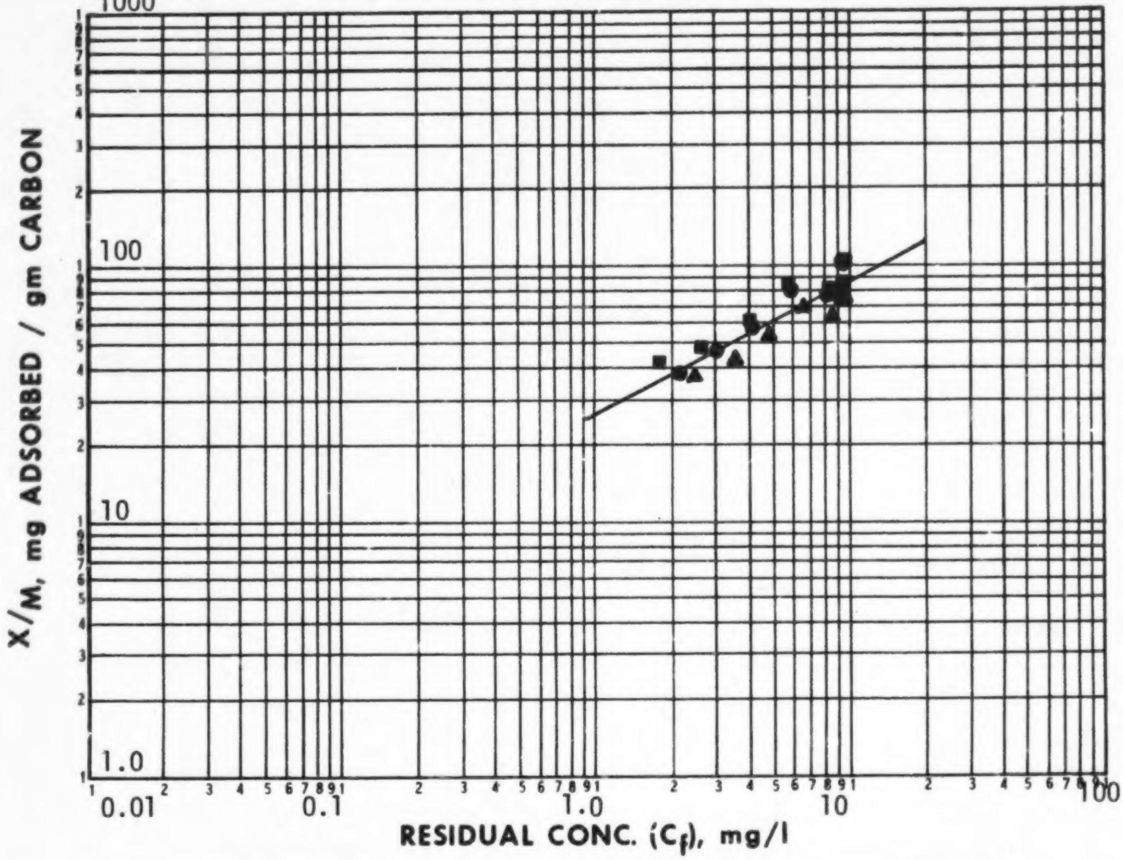
C_o, mg/l	
1.0	36
0.1	12
0.01	3.8

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 264 nm

REMARKS:

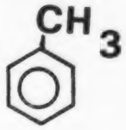
COMPOUND: Thymine



	● pH= 3.0			■ pH= 7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	10.05			10.10			10.07		
5	9.54	0.51	102	9.58	0.52	104	9.68	0.39	78
10	9.28	0.77	77	9.21	0.89	89	9.31	0.76	76
25	8.07	1.98	79	8.08	2.02	81	8.48	1.59	64
50	6.03	4.02	80	5.82	4.28	86	6.59	3.48	70
100	4.22	5.83	58	3.96	6.14	61	4.75	5.32	53
150	3.04	7.01	47	2.72	7.38	49	3.56	6.51	43
200	2.19	7.86	39	1.77	8.33	42	2.51	7.56	38

COMPOUND: Toluene

STRUCTURE:



FORMULA: C_7H_8 **MOL. WT.** 92.14

FREUNDLICH PARAMETERS	pH		
	5.6		
K	26.1		
1/n	0.44		
Corr. Coef. r	0.89		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	26		
0.1	9.4		
0.01	3.4		
0.001	1.2		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	96	290	820
0.1		27	81
0.01			7.4

GRANULAR CARBON COLUMN

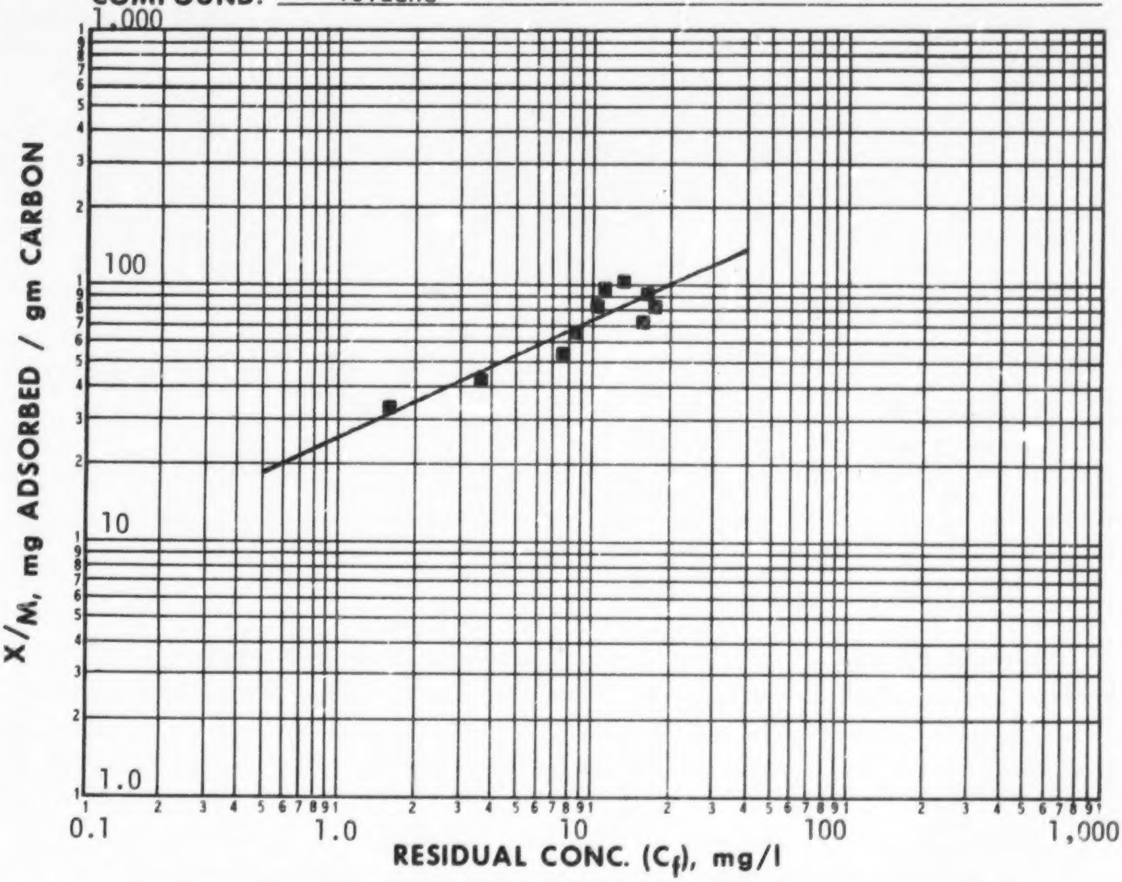
C_o, mg/l	
1.0	38
0.1	11
0.01	2.9

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 208.8 nm.

REMARKS:

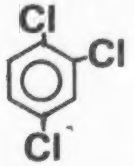
COMPOUND: Toluene



	■ pH= 5.6			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	18.48								
5	18.07	0.41	82						
10	17.56	0.92	92						
25	16.70	1.78	71.2						
50	13.20	5.28	105.6						
75	11.00	7.48	99.7						
100	10.33	8.15	81.5						
150	8.36	10.12	67.5						
200	7.65	10.83	54.2						
350	3.67	14.81	42.3						
500	1.71	16.77	33.5						

COMPOUND: 1,2,4-Trichlorobenzene

STRUCTURE:



FORMULA: $C_6H_3Cl_3$ **MOL. WT.** 181.45

FREUNDLICH PARAMETERS	pH		
	5.3		
K	157		
1/n	0.31		
Corr. Coef. r	0.84		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	157		
0.1	77.6		
0.01	38.4		
0.001	19.0		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_0, mg/l	0.1	0.01	0.001
1.0	12	26	52
0.1		2.3	5.2
0.01			0.5

GRANULAR CARBON COLUMN

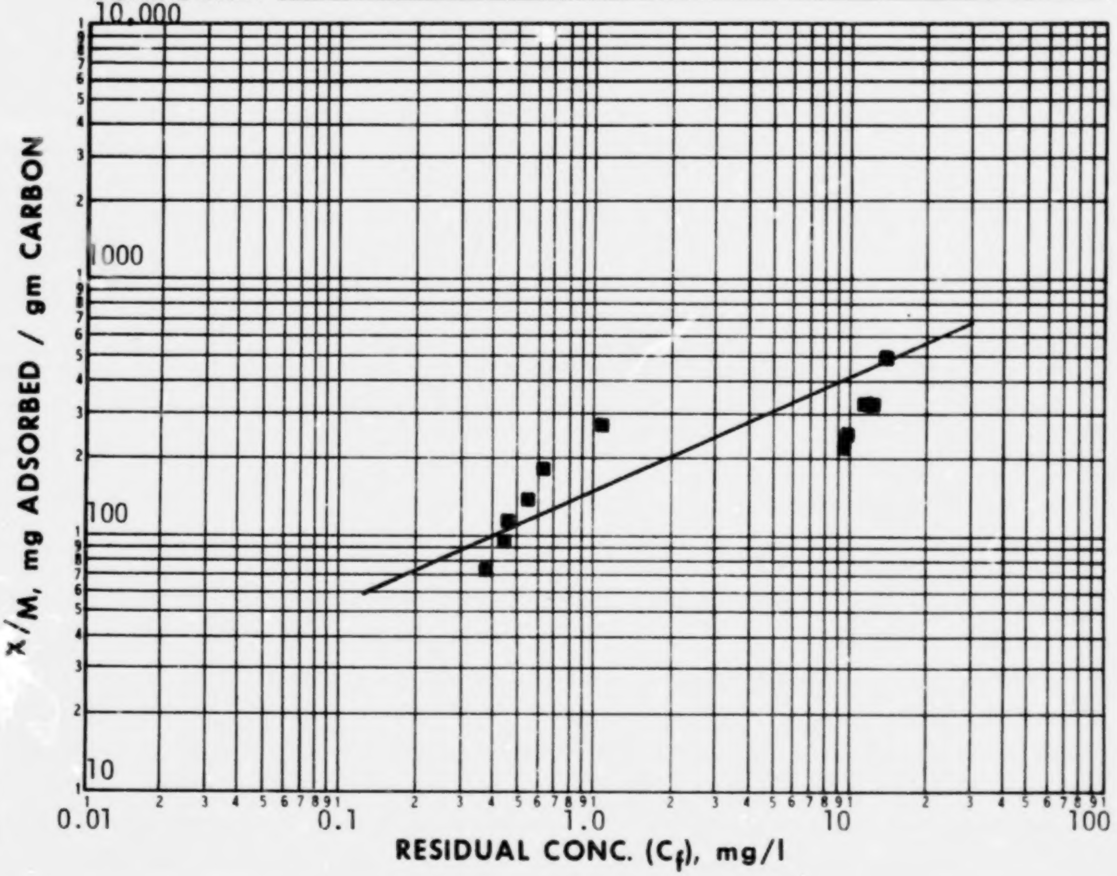
C_0, mg/l	
1.0	6.4
0.1	1.3
0.01	0.3

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 226.5 nm.

REMARKS:

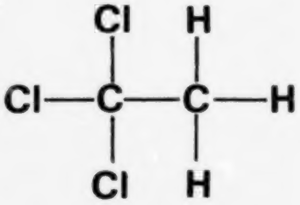
COMPOUND: 1,2,4-Trichlorobenzene



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	15.01								
2.5	13.76	1.25	500						
5	13.43	1.58	316						
10	11.76	3.25	325						
20	9.82	5.19	260						
25	9.36	5.65	226						
50	1.10	13.91	278						
75	0.62	14.39	192						
100	0.53	14.48	145						
125	0.46	14.55	116						
150	0.43	14.58	97.2						
200	0.38	14.63	73.2						

COMPOUND: 1,1,1-Trichloroethane

STRUCTURE:



FORMULA: $C_2H_3Cl_3$ **MOL. WT.** 133.41

FREUNDLICH PARAMETERS	pH		
	5.3		
K	2.48		
1/n	0.34		
Corr. Coef. r	0.97		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	2.5		
0.1	1.1		
0.01	0.51		
0.001	0.23		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	800	1,900	4,300
0.1		180	430
0.01			39

GRANULAR CARBON COLUMN

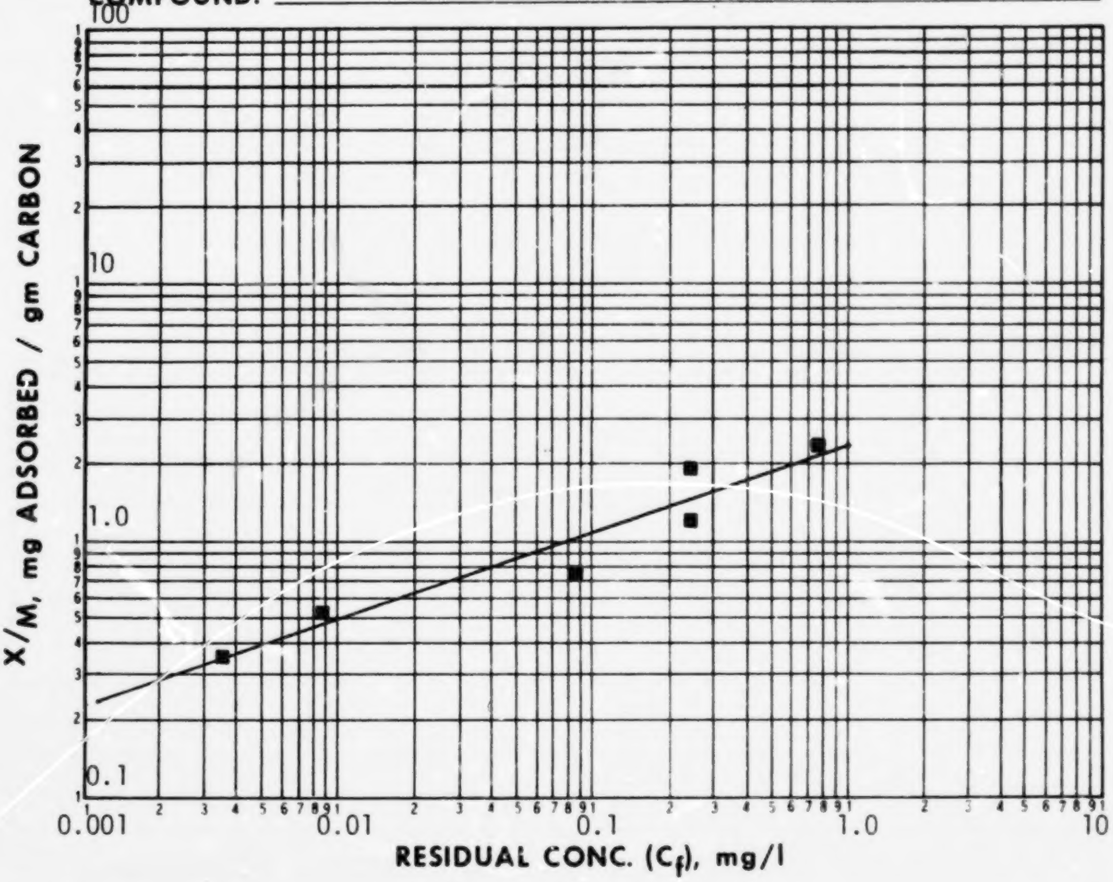
C_o, mg/l	
1.0	400
0.1	90
0.01	20

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G. C. - Purge and Trap

REMARKS:

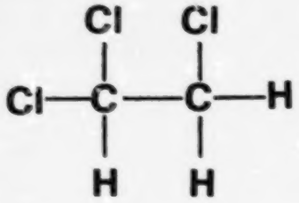
COMPOUND: 1,1,1-Trichloroethane



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	1.000								
96	0.768	0.232	2.41						
385	0.240	0.760	1.97						
577	0.238	0.762	1.32						
1154	0.084	0.916	0.794						
1923	0.0087	0.991	0.516						
2692	0.0035	0.9965	0.370						

COMPOUND: 1,1,2-Trichloroethane

STRUCTURE:



$$\mathrm{Cl-\overset{Cl}{\underset{H}{C}}-\overset{Cl}{\underset{H}{C}}-H}$$

FORMULA: $C_2H_3Cl_3$ **MOL. WT.** 133.41

FREUNDLICH PARAMETERS	pH		
	5.3		
K	5.81		
1/n	0.60		
Corr. Coef. r	0.97		
INITIAL CONC. mg/l	**ADSORPTION CAPACITY, mg/gm**		
1.0	5.8		
0.1	1.4		
0.01	0.36		
0.001	0.09		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

	C_f, mg/l		
C_o, mg/l	0.1	0.01	0.001
1.0	620	2,700	11,000
0.1		250	1,100
0.01			99

GRANULAR CARBON COLUMN

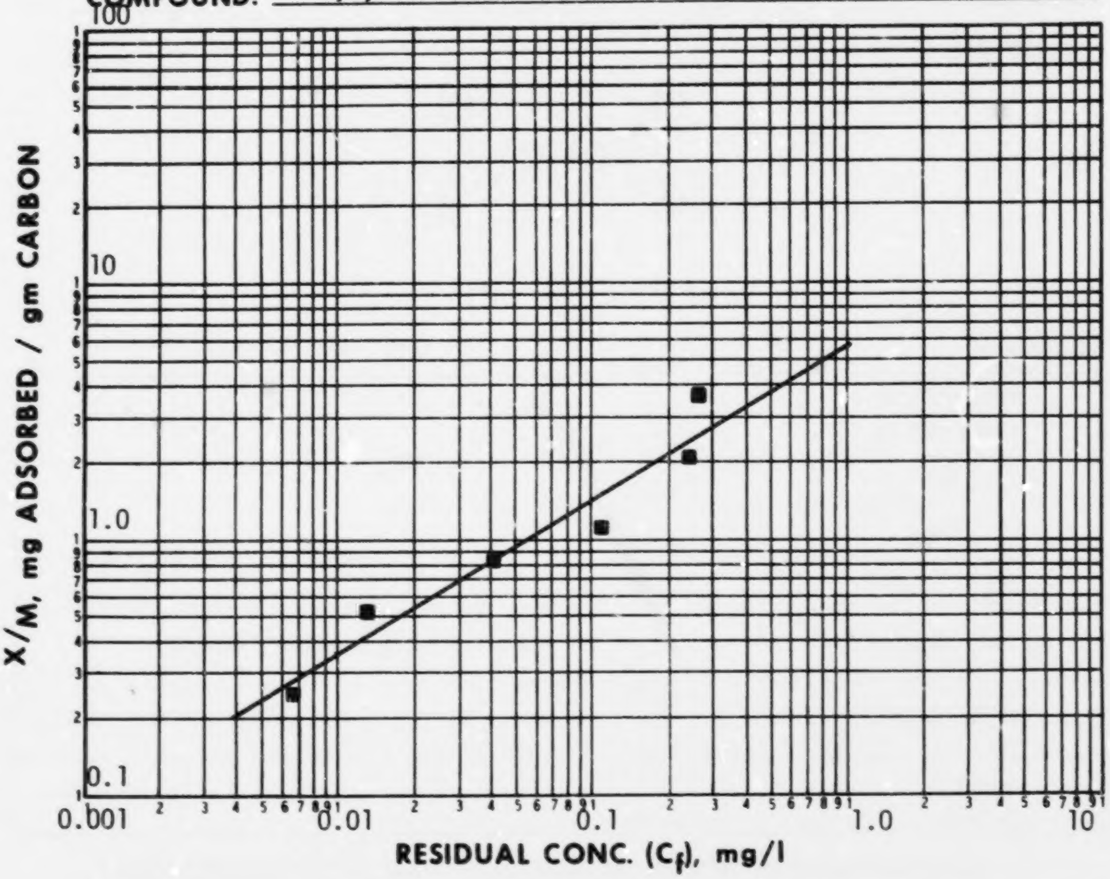
C_o, mg/l	
1.0	170
0.1	69
0.01	28

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G.C. Purge and Trap

REMARKS:

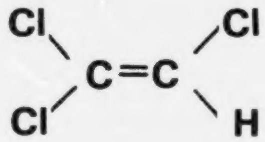
COMPOUND: 1,1,2-Trichloroethane



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	1.000								
192	0.271	0.729	3.79						
385	0.230	0.770	2.00						
769	0.110	0.890	1.16						
1154	0.041	0.959	0.831						
1923	0.013	0.987	0.513						
3846	0.006	0.994	0.258						

COMPOUND: Trichloroethene (Trichloroethylene)

STRUCTURE:



FORMULA: C_2HCl_3 **MOL. WT.** 131.39

FREUNDLICH PARAMETERS	pH		
	5.3		
K	28.0		
1/n	0.62		
Corr. Coef. r	0.99		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	28		
0.1	6.7		
0.01	1.6		
0.001	0.38		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	130	620	2,600
0.1		56	260
0.01			23

GRANULAR CARBON COLUMN

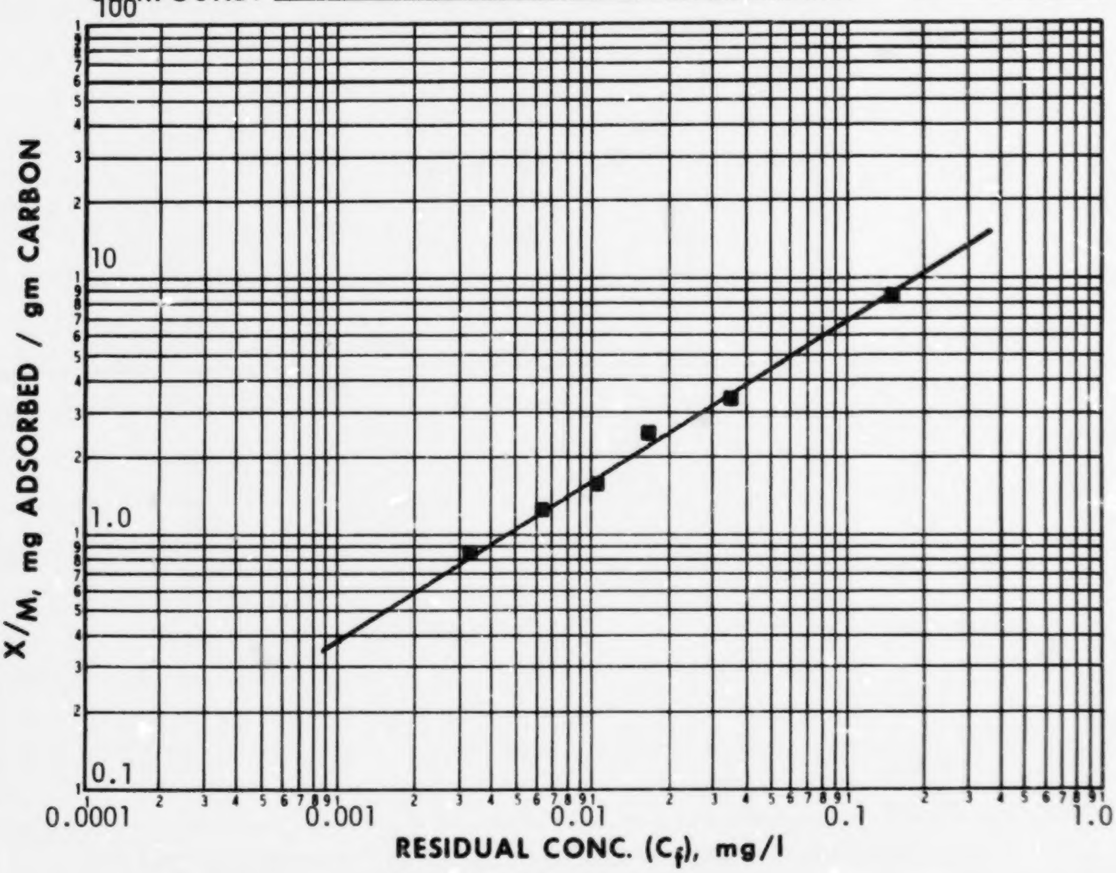
C_o, mg/l	
1.0	36
0.1	15
0.01	6.3

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G. C. Purge and Trap

REMARKS:

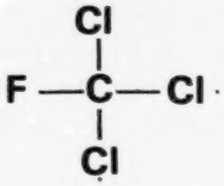
COMPOUND: Trichloroethene (Trichloroethylene)



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	1.000								
96	0.164	0.836	8.70						
289	0.035	0.965	3.35						
385	0.018	0.982	2.55						
577	0.0104	0.990	1.71						
769	0.0061	0.994	1.29						
1154	0.0052	0.995	0.862						

COMPOUND: Trichlorofluoromethane

STRUCTURE:



FORMULA: CCl_3F **MOL. WT.** 137.4

FREUNDLICH PARAMETERS	pH		
	5.3		
K	5.6		
1/n	0.24		
Corr. Coef. r	0.90		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	5.6		
0.1	3.2		
0.01	1.8		
0.001	1.1		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON
C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	280	530	930
0.1		48	92
0.01			8.4

GRANULAR CARBON COLUMN

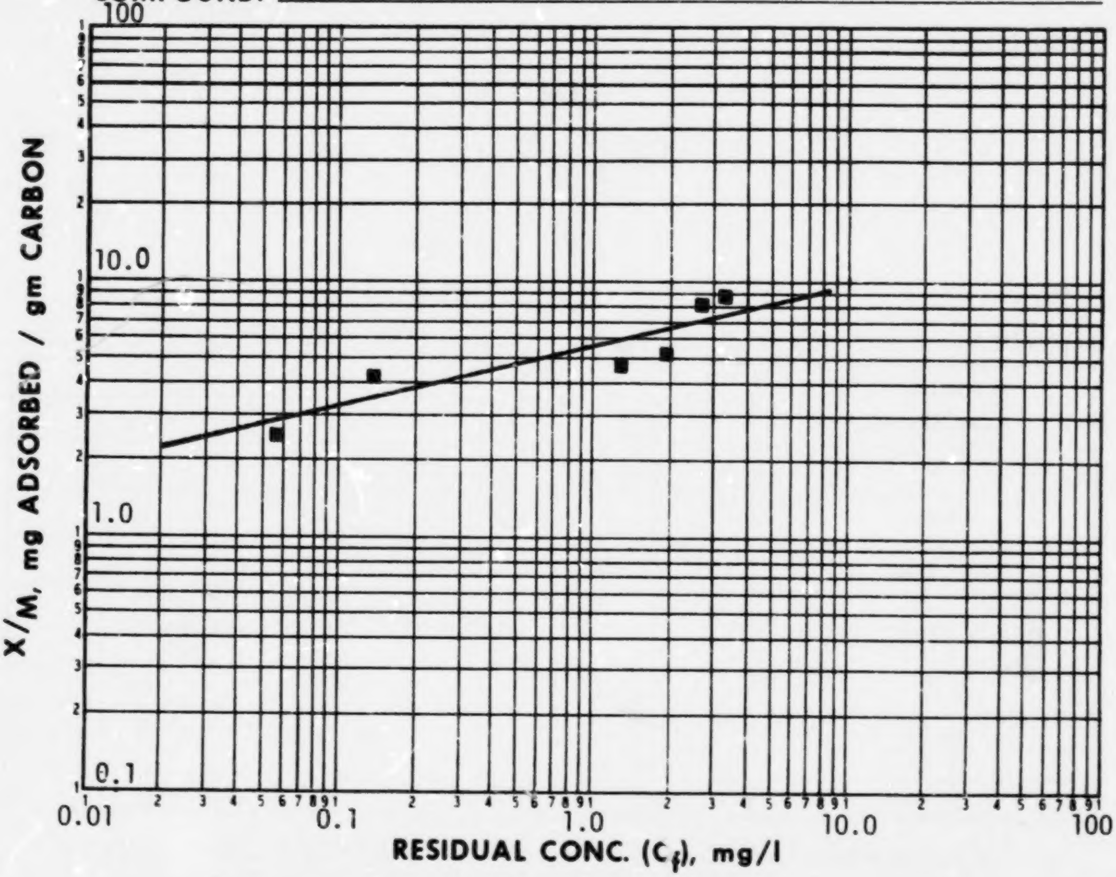
C_o, mg/l	
1.0	180
0.1	31
0.01	5.6

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: G. C. Purge and Trap

REMARKS:

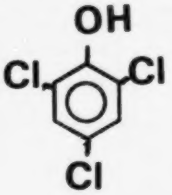
COMPOUND: Trichlorofluoromethane



	■ pH= 5.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	5.000								
192	3.27	1.73	8.98						
289	2.68	2.32	8.02						
577	1.98	3.02	5.23						
769	1.31	3.69	4.80						
1154	0.138	4.86	4.21						
1923	0.056	4.94	2.57						

COMPOUND: 2,4,6-Trichlorophenol

STRUCTURE:



FORMULA: $C_6H_9OCl_3$ **MOL. WT.** 197.45

FREUNDLICH PARAMETERS	pH		
	3.0	6.0	9.0
K	219.0	155.1	130.1
1/n	0.29	0.40	0.39
Corr. Coef. r	0.97	0.94	0.98
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	219.0	155.1	130.1
0.1	113.2	61.2	52.9
0.01	58.5	24.2	21.5
0.001	30.2	9.5	8.7

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	15	41	105
0.1		3.7	10.4
0.01			0.9

GRANULAR CARBON COLUMN

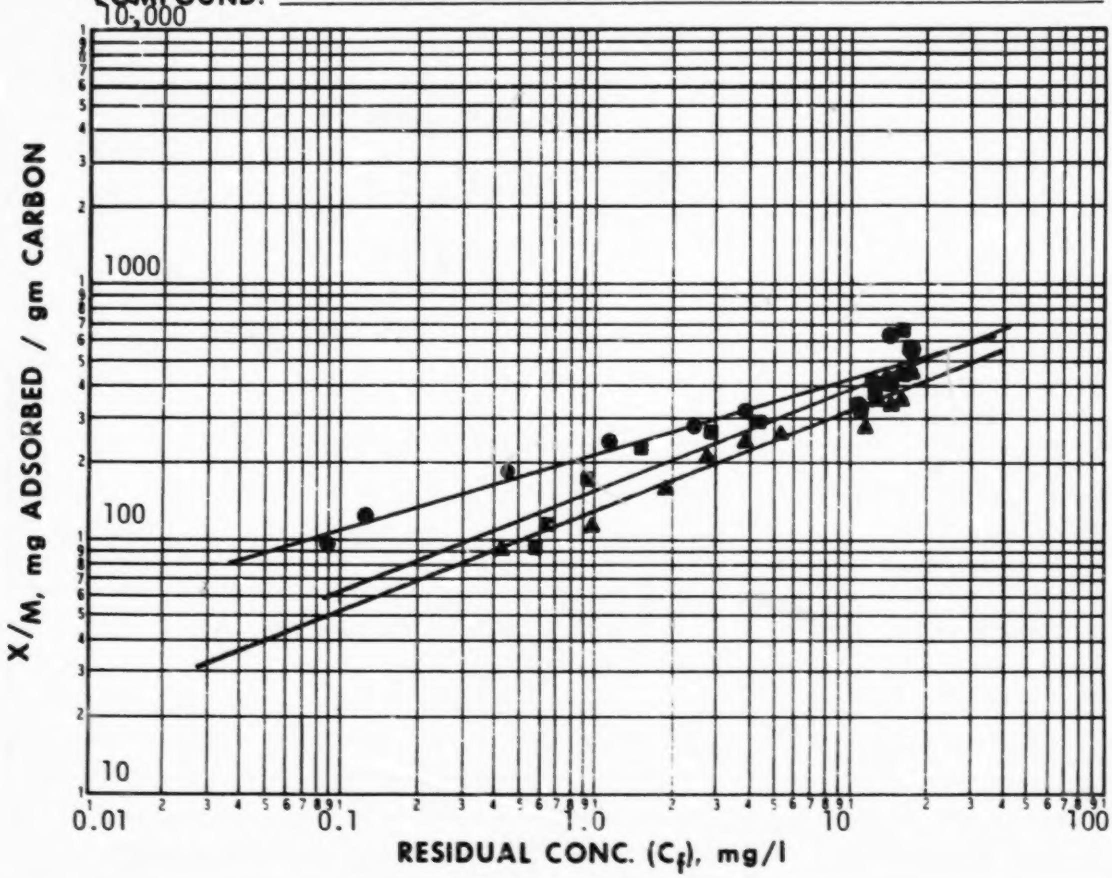
C_o, mg/l	
1.0	6.4
0.1	1.6
0.01	0.4

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 312.6 nm.

REMARKS:

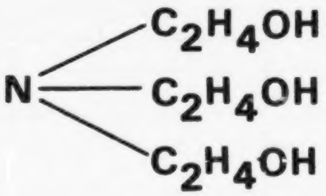
COMPOUND: 2,4,6-Trichlorophenol



	● pH= 3.0			■ pH= 6.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	19.66			19.11			16.65		
2.5	18.24	1.42	568	17.38	1.73	692	17.50	1.15	460
5	16.54	3.12	624	16.85	2.26	452	16.80	1.85	370
10	15.37	4.29	429	15.09	4.02	402	15.23	3.42	342
15	13.31	6.35	423	13.30	5.81	387	13.24	5.41	361
25	11.05	8.61	344	11.01	8.10	324	11.44	7.21	288
50	3.98	15.66	314	4.32	14.79	296	5.20	13.45	269
60	2.47	17.19	286	2.85	16.26	271	3.93	14.72	245
75	1.22	18.44	248	1.63	17.48	233	2.79	15.86	212
100	0.47	19.19	192	0.94	18.17	182	1.90	16.75	168
150	0.13	19.53	130	0.65	18.46	123	0.98	17.67	118
200	0.09	19.57	98	0.58	18.53	93	0.42	18.23	91

COMPOUND: Triethanolamine

STRUCTURE:



FORMULA: $C_6H_{15}NO_3$ **MOL. WT.** 149.19

FREUNDLICH PARAMETERS	pH		
K			
1/n			
Corr. Coef. r			
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l			

GRANULAR CARBON COLUMN

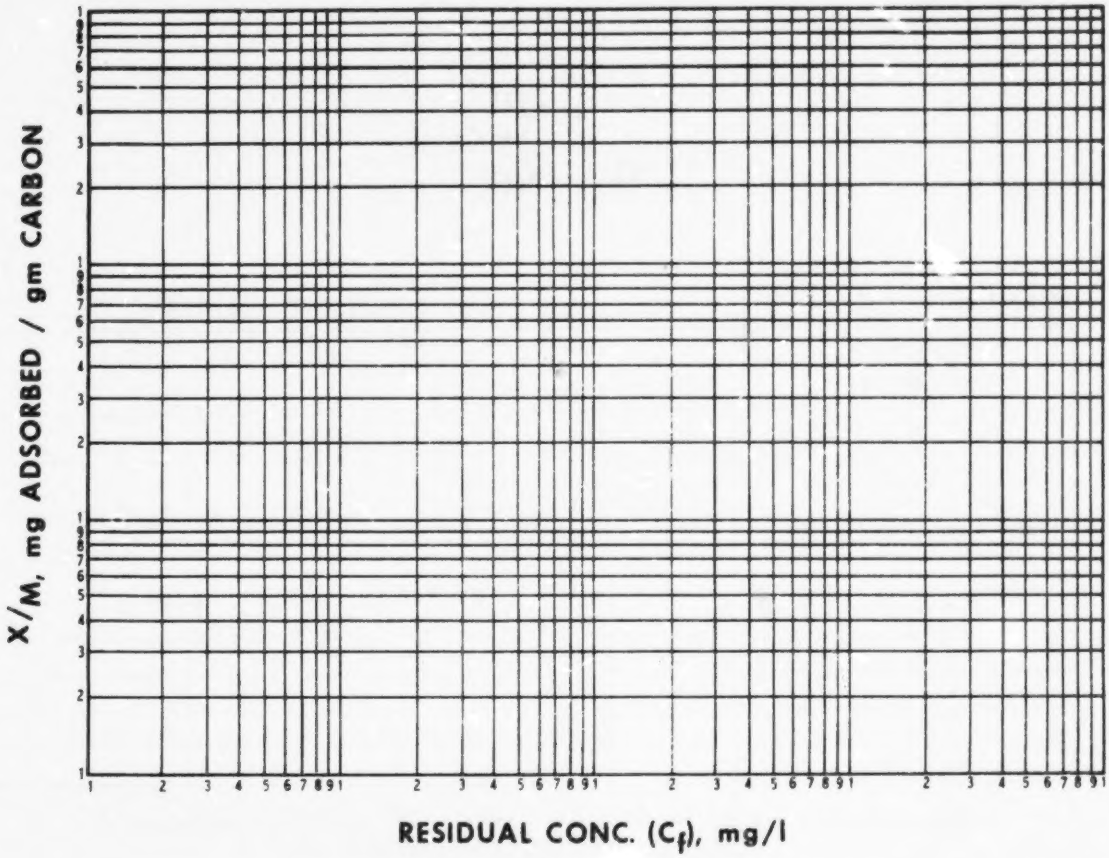
C_o, mg/l	

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Total Organic Carbon

REMARKS: Not adsorbed

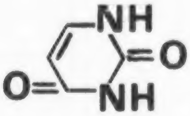
COMPOUND: Triethanolamine



	pH= 3.0			pH= 7.0			pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	13.0			15.2			13.0		
5	12.6			14.4			13.0		
10	12.2			13.8			12.4		
25	12.8			12.4			11.8		
50	12.4			13.8			12.2		
100	13.0			12.4			11.2		
150	12.2			11.0			10.6		
200	12.8			10.8			10.8		

COMPOUND: Uracil

STRUCTURE:



FORMULA: $C_4H_4N_2O_2$ **MOL. WT.** 112.09

FREUNDLICH PARAMETERS	pH		
	All data pooled		
K	11		
1/n	0.63		
Corr. Coef. r	0.92		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
1.0	11		
0.1	2.6		
0.01	0.60		
0.001	0.14		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	0.1	0.01	0.001
1.0	350	1,700	7,100
0.1		150	710
0.01			64

GRANULAR CARBON COLUMN

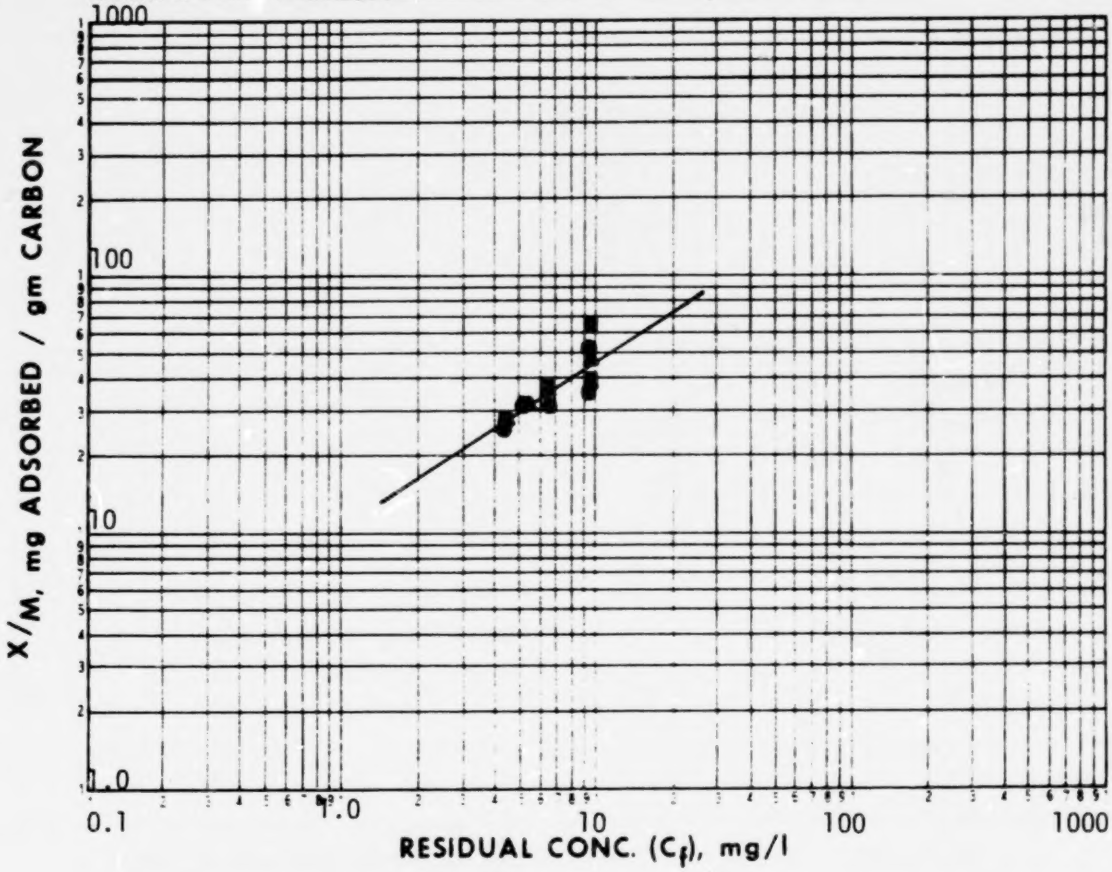
C_o, mg/l	
1.0	91
0.1	38
0.01	17

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 258 nm

REMARKS:

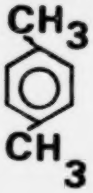
COMPOUND Uracil



	● pH= 3.0			■ pH=7.0			▲ pH= 9.0		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	C_o-C_f=X	X/M	C_f	C_o-C_f=X	X/M
0	9.87			9.95			9.94		
5	9.61	0.26	52	9.62	0.33	66	9.70	0.24	48
10	9.51	0.36	36	9.55	0.40	40	9.55	0.39	39
100	6.76	3.11	31	6.20	3.75	37.5	6.25	3.69	37
150	5.21	4.66	31	5.20	4.75	32	5.35	4.59	31
200	4.41	5.46	27	4.29	5.66	28	4.37	5.57	28

COMPOUND: P-Xylene

STRUCTURE:



FORMULA: C_8H_{10} **MOL. WT.** 106.2

FREUNDLICH PARAMETERS	pH		
	7.3		
K	85		
1/n	0.19		
Corr. Coef. r	0.93		
INITIAL CONC. mg/l	ADSORPTION CAPACITY, mg/gm		
10	130		
1.0	85		
0.1	54		
0.01	35		

CALCULATED CARBON REQUIREMENTS TO ACHIEVE INDICATED CHANGE IN CONCENTRATION (a)

SINGLE STAGE POWDERED CARBON

C_f, mg/l

C_o, mg/l	1.0	0.1	0.01
1.0		15	24
0.1			2.2
0.01			

GRANULAR CARBON COLUMN

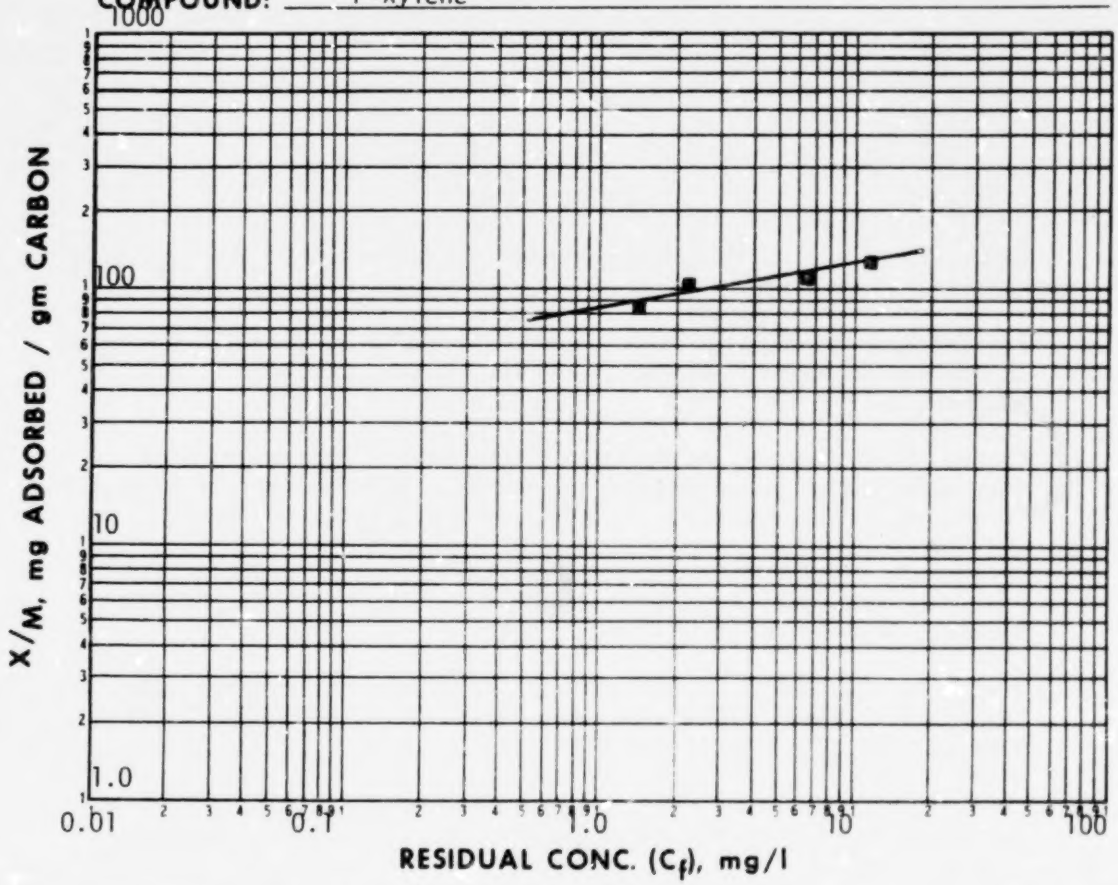
C_o, mg/l	
1.0	12
0.1	1.9
0.01	0.3

(a) Carbon doses in mg/l at neutral pH.

ANALYTICAL METHOD: Ultraviolet Spectroscopy 267 nm

REMARKS:

COMPOUND: P-Xylene



	■ pH= 7.3			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M	C_f	$C_o-C_f=X$	X/M
0	18.0								
5.0	12.0	6.0	130						
100	6.4	11.6	116						
150	2.2	15.8	105						
200	1.5	16.5	83						

REFERENCES

1. Maugh, T. H. II. Chemicals: How Many Are There? Science, 199:162, 1978.

2. Shackelford, W. M., and L. H. Keith. Frequency of Organic Compounds Identified in Water. EPA-608/4-76-062, USEPA, Cincinnati, Ohio, December 1976.

3. Linner, E. R., and R. A. Gortner. Interfacial Energy and the Molecular Structure of Organic Compounds. III. The Effect of Organic Structure on Adsorbability. J. Phys. Chem., 39:35, 1935.

4. Morris, J. C., and W. J. Weber, Jr. Adsorption of Biochemically Resistant Materials from Solution, Part 1. U. S. Public Health Service, AWTR-9, Report 999-WP-11, 1964.

5. Morris, J. C., and W. J. Weber, Jr. Adsorption of Biochemically Resistant Materials from Solution, Part II. U. S. Public Health Service, AWTR-16, Report 999-WP-33, 1966.

6. Ward, T. M., and F. W. Getzen. Influence of pH on the Adsorption of Aromatic Acids on Activated Carbon. Environ. Sci. & Technol., 4:(1)64, 1970.

7. Aly, O. M., and S. D. Faust. Removal of 2,4-Dichlorophenoxyacetic Acid Derivatives from Natural Waters. J. Am. Water Works Assn., 65:(2)221, 1965.

8. Dedrick, R. L., and R. B. Beckman. Kinetics of Adsorption by Activated Carbon from Dilute Aqueous Solution. Chem. Engr. Progr. Symp. Ser., 63, 74, 1967.

9. Weber, W. J., Jr., and J. P. Gould. Organic Pesticides in the Environment. Advan. Chem. Ser., 60. R. F. Gould (Ed.), Am. Chem. Soc., Washington, D. C., 1966.

10. DiGiano, F. J., and W. J. Weber, Jr. Technical Publication T-69-1. Dept. of Civil Engineering, Univ. of Michigan, Ann Arbor, 1969.

11. El-Dib, M. A., F. M. Ramadan, and M. Ismail. Adsorption of Sevin and Baygon on Granular Activated Carbon. Water Research, 9:795, 1975.

12. Bernardin, F. E., Jr., and E. M. Froelich. Practical Removal of Toxicity by Adsorption. Presented at the 30Th Annual Purdue Industrial Wastes Conference, May 8-9, 1975, Purdue University, Lafayette, Indiana.

13. Lawrence, J., and H. M. Tosine. Adsorption of Polychlorinated Biphenyls from Aqueous Solutions and Sewage. Environ. Sci. & Technol., 10:381, 1976.

14. Al-Bahrani, K. S., and R. J. Martin. Adsorption Studies Using Gas-Liquid Chromatography: I. Effect of Molecular Structure. Water Research, 10:731, 1976.

15. Argaman, Y. Treatment of Chlorinated Hydrocarbons' Wastewater By Activated Carbon Adsorption With Steam Regeneration. Prog. Wat. Tech., 9:65, 1977.

16. Singer, P. C., and C. Yen. Adsorption of Alkyl Phenols by Activated Carbon. Activated Carbon Adsorption of Organics from the Aqueous Phase, Proceedings of the September 1978 A C S Symposium, Miami Beach, Florida. (I. H. Suffet and M. J. McGuire, editors), Ann Arbor, Michigan. (In press 1980).

17. Muren, C. J., and V. L. Snoeyink. Competitive Adsorption of 2,4-Dichlorophenol and 2,4,6-Trichlorophenol in the Nanomolar to Micromolar Concentration Range. Environ. Sci. & Technol., 13:305, 1979.

18. Steiner, J., and J. E. Singley. Methoxychlor Removal from Potable Water. J. AWWA, 71:284, 1979.

19. El-Dib, M. A., and M. I. Badawy. Adsorption of Soluble Aromatic Hydrocarbons on Granular Activated Carbon. Water Research, 13:255, 1979.

20. Peel, R. G., and A. Benedek. Attainment of Equilibrium in Activated Carbon Isotherm Studies. Environ. Sci. & Technol., 14:66, 1980.

21. Fochtman, E. G., and R. A. Dobbs. Adsorption of Carcinogenic Compounds by Activated Carbon. Activated Carbon Adsorption of Organics from the Aqueous Phase., Proceedings of the September 1978 ACS Symposium in Miami Beach, Florida. (I. H. Suffet and M. J. McGuire, editors), Ann Arbor Sci. Publ., Ann Arbor, Michigan. (In press 1980).

22. Bellar, T. A., and J. J. Lichtenberg. Determining Volatile Organics at Microgram-per-Litre Levels by Gas Chromatography. J. AWWA, 66:739, 1974.

23. Austern, B. M., R. A. Dobbs, and J. M. Cohen. Gas Chromatographic Determination of Selected Organic Compounds Added to Wastewater. Environ. Sci. & Technol., 9:588, 1975.

24. Environmental Protection Agency. Guidelines Establishing Test Procedures for the Analysis of Pollutants. 40 CFR Part 136, Federal Register, 44:69464, December 3, 1979.

25. May, W. E., and S. P. Wasik. Determination of the Solubility Behavior of Some Polycyclic Aromatic Hydrocarbons in Water. Anal. Chem., 50:997, 1978.

26. Hassler, J. W., and W. E. McMinn. The Nature of Active Carbon. Ind. Eng. Chem., 37:645, 1945.

27. Fochtman, E. G., and W. Eisenberg. Treatability of Carcinogenic and Other Hazardous Organic Compounds. Contract No. CI-68-03-2559, EPA-600/2-79-097, USEPA, Cincinnati, Ohio, August 1979.

BIBLIOGRAPHY

Cheremisinoff, P. N., and F. Ellerbush, (editors), Carbon Adsorption Handbook. Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan; 1978.

Hassler, J. W., Purification With Activated Carbon. Chemical Publishing Company, Incorporate, New York, New York; 1974.

Kipling, J. J. Adsorption from Solutions of Non-Electrolytes. Academic Press, New York, New York; 1965.

Mattson, J. S., and H. B. Mark, Jr. Activated Carbon-Surface Chemistry and Adsorption from Solution. Marcel Dekker, Incorporated, New York, New York; 1971.

Verschueren, K. Handbook of Environmental Data on Organic Chemicals. Van Nostrand Reinhold Company, New York, New York; 1977.

APPENDIX A

ACTIVATED CARBON ADSORPTION ISOTHERM PROTOCOL

1. General Discussion

1.1 Purpose of Test

Application of activated carbon for removal of solutes from aqueous solution is based on a property known as the adsorption capacity. The adsorption isotherm procedure is a method for the determination of the adsorptive capacity of activated carbons. The test can be used to compare adsorption capacities of different carbons for a given solute or to measure the adsorbability of different solutes on a given carbon.

2. Apparatus

2.1 Jar mill, jar and cylindrical grinding medium

2.2 Standard 200 mesh and 400 mesh sieves with 0.0029 inch (73.6μ) and 0.0015 inch (38.1μ) openings and mechanical sieve shakers.

2.3 Coordinated magnetic stirrers and stirring bars or jar test apparatus.

2.4 Ground-glass stoppered reagent bottles (1000 ml or appropriate volume).

2.5 Volumetric dispensing pipettes.

2.6 Filtration equipment; select from the following: 0:45μ membrane filter, sintered silver filter disc, glass fiber filter paper, syringe equipped with a Swinney filter holder, or pressure filter apparatus.

2.7 Analytical balance

2.8 Drying oven

2.9 Desiccator

2.10 pH meter

3. Reagents

All reagents must be prepared with "organic-free " distilled water. Treatment of conventional distilled water with large amounts of activated carbon in a column or batch process is suitable for this purpose. If isotherm tests are to be conducted on volatile compounds the carbon-treated distilled water should be boiled for 15 - 20 minutes or purged over night with inert gas in order to remove volatile compounds which may contaminate distilled water during distillation or storage.

3.1 Preparation of adsorbent:

Although granular carbons can be compared or evaluated in their original form by means of a batch test, the general procedure is to pulverize the adsorbent. Use of pulverized carbon assures more rapid attainment of equilibrium. If the adsorbent is in granular form, place in jar with grinding medium. Jar should not be more than half full to insure efficient grinding of the carbon. Place on a jar mill until sample is pulverized. Sieve the pulverized material through a 200-mesh (0.0736 mm) sieve and retain on a 400-mesh (0.038/mm) sieve. Return carbon which did not pass through the 200-mesh sieve to the jar for additional grinding. Repeat procedure until approximately 90% of the sample passes the 200-mesh sieve. Powdered carbons are classified as described above without the grinding operation. Use the 200/400 mesh fraction for isotherm testing. Dry the classified carbon overnight in a drying over ast 105° C. Cool in a desiccator and store until needed for experimental purposes.

3.2 Preparation of activated carbon stock slurry: weigh out 50.00 grams of oven-dried and cooled pulverized carbon and transfer to a one-liter volumetric flask. Dilute to mark with "organic-free" distilled water. One ml of stock suspension contains 50 mg carbon. Prepare other working standard slurries by serial dilution of the stock slurry. Transfer slurries to appropriate flasks containing dispensing pipettes to provide a wide range of carbon concentrations. Table I lists the carbon dosages obtained with various volumes of stock slurry for one-liter sample volumes.

Table 1. Carbon Dosages for Given Pipette Volumes

Volume of Dispensing Pipette, (ml)	Carbon Dosage,* (mg/l)
5	250
10	500
15	750
20	1000
25	1250

* Not corrected for dilution of the one-liter sample volume

Dilution of the stock slurry by 1:10 and 1:100 would result in carbon doses 1/10 and 1/100 of those shown in Table 1.

3.3 Hydrochloric acid 6N. Dilute concentrated HCl 1:1 with "organic-free" distilled water.

3.4 Sodium hydroxide 6N. Add 240 grams of NaOH pellets to one liter of "organic-free" distilled water.

4. Procedure

4.1 If the test solution contains volatile or semivolatile components, place one-liter samples in a series of ground-glass stoppered reagent bottles. Add increasing carbon dosages to each successive sample. Add no carbon to one sample and use as a control. An initial concentration of 10 mg/l of test compound might require carbon dosages of 5, 10, 25, 50, 100, 250, 500, and 1000 mg/l. A preliminary isotherm may be required to bracket the desired range of dosages. Immediately after addition of the carbon dose, fill the reagent bottle to the bottom of the ground-glass stopper with additional test solution so that no air space remains. This will minimize loss of volatile solutes. Reagent bottle volumes should be recorded on the bottle and closely matched bottles used as a set. One-liter reagent bottles typically have a total volume of 1070-1090 ml. Carbon doses and test solution concentrations can be corrected for dilution associated with completely filling the ground-glass stoppered reagent bottles. In general, this correction is small and can be ignored.

4.2 Place the carbon-dosed samples on a coordinated magnetic stirrer apparatus and stir the control and samples for two hours. At the conclusion of the contact period separate the pulverized carbon from the test solution by an appropriate filtration procedure and analyze for the component of interest. Choice of filtration process will depend upon the characteristics of the test solution and the method of chemical analysis. Analysis of the control or a standard solution before and after filtration will determine whether or not a proper filtration method has been selected. Filtration of the sample should not result in a significant change in concentration of components.

In the case of volatile compounds, a syringe equipped with a Swinney filter holder can be used if the volume of filtrate required for analysis is small (i.e., analytical methods such as purge and trap gas chromatography, total organic carbon, or ultraviolet spectroscopy). Pressure filters can be used if larger volumes are required for analysis. Vacuum filtration with pre-washed membrane filters is suitable for solution containing nonvolatile components, provided adsorption losses are not encountered on the membrane. If adsorption losses are evident, sintered silver membranes or glass fiber paper can be used for separation of the pulverized carbon. Carbon can also be separated by centrifugation.

4.3 Analysis of the filtrate: The concentration of solute in equilibrium with each carbon dose is measured by an appropriate quantitative method such as spectrophotometry, colorimetry, total organic carbon, gas chromatography, evaporation to residue or other analytical technique.

5. Treatment of Data

5.1 Calculation of adsorption capacity: Activated carbon adsorption isotherm data are usually plotted according to the Freundlich equation. Detailed discussion of the equation and its uses can be found in the literature. Although the equation is empirical, it is nonetheless widely used and has been found to adequately describe the adsorption process in dilute solution. The Freundlich equation has the form:

$$X/M = K\,C_f^{1/n}$$

where $X = C_o - C_f$ which is the amount of solute adsorbed from a given volume of solution

C_o = initial concentration of solute in the untreated solution

C_f = final concentration in the treated solution at equilibrium

M = weight of activated carbon added to the solution

K & 1/n = empirical constants

Data are fitted to the logarithmic form of the above equation which can be written as follows:

$$\log X/M = \log K + 1/n \log C_f \qquad (2)$$

For dilute solutions this equation yields a straight line with a slope of 1/n and an intercept equal to the value of K (when Cf = 1) when X/M is plotted as a function of Cf on logarithmic paper. The intercept is an indicator of adsorption capacity and the slope of adsorption intensity.

A convenient form for tabulation of adsorption isotherm data is shown on the standard data form. Carbon dosages are shown in the left-hand column. The next column for each set of data contains the residual concentrations remaining in solution after carbon treatment. The C_f value for the control sample corresponding to the zero carbon dose is the C_o value. The amount of solute adsorbed (X) is calculated by subtracting each C_f value from C_o and is summarized in the appropriate column. Dividing "X" in mg of solute by the carbon dose in grams gives the adsorption capacity (X/M) per gram of carbon shown in the final column for each set of data. X/M values are plotted as a function of C_f according to equation (2) on logarithmic paper.

5.2 Least squares regression analysis may be used to locate the best-fit line for the plotted data points. A small programmable calculator is convenient for this purpose.

5.3 Extrapolation of the plotted isotherm to C_0 (C_f value with zero carbon dose) gives the adsorption capacity at the initial concentration by noting the corresponding value from the X/M axis. Adsorption capacities at other concentrations can be read in the same manner. As the Freundlich equation states the adsorption capacity of carbon, X/M, is a function of the equilibrium concentration, C_f, of the solute.

5.4 Freundlich parameters: The plotted isotherm can be used to obtain the Freundlich parameters K and 1/n. K can be read from the X/M axis at $C_f = 1$. The slope (1/n) can be measured graphically using a ruler (i.e., mm rise/mm span) or taken from the programmable calculator. These parameters are useful in comparing the adsorbability of solutes and in rating the efficiency of different activated carbons.

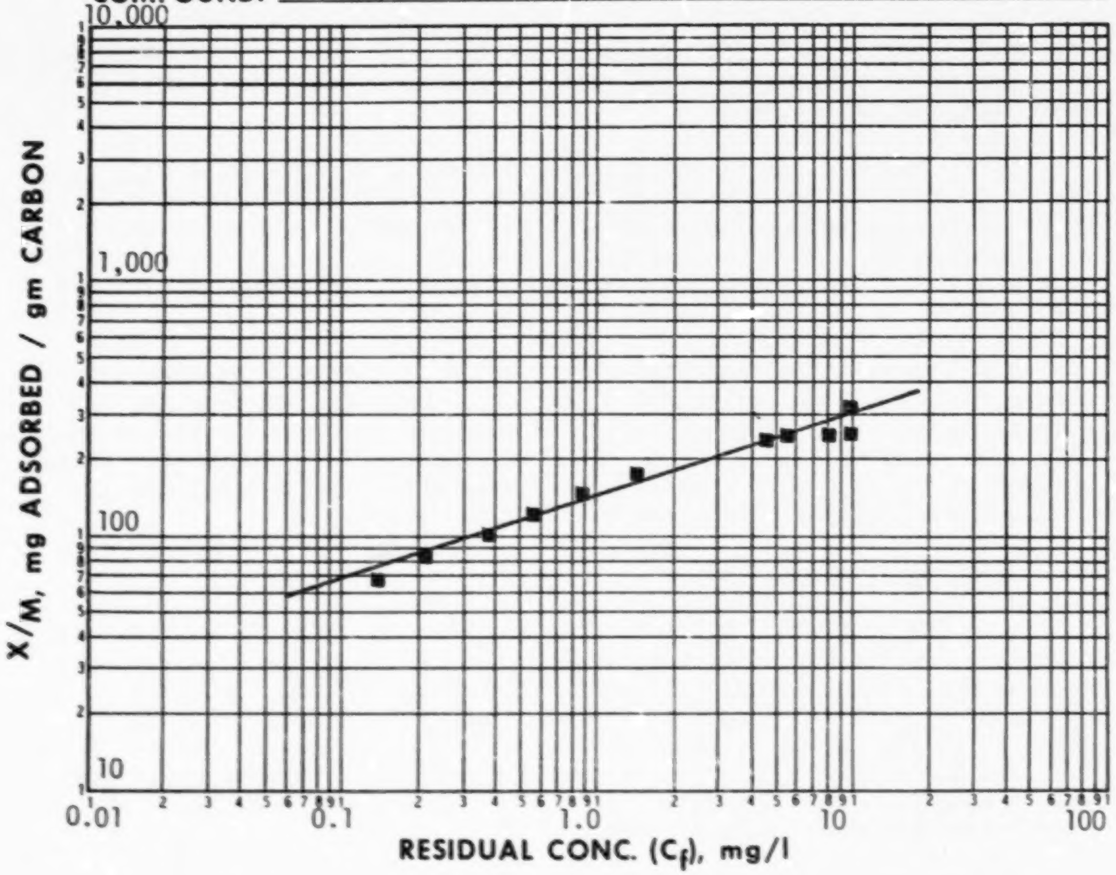
6. Alternative Procedures

6.1 The pH of the test solution can affect the equilibrium adsorption capacity. For acidic solutes adsorption is favored at low pH while basic compounds are more strongly adsorbed at higher pH values. Solution pH can be adjusted with hydrochloric acid or sodium hydroxide prior to addition of the carbon if these effects are to be measured. Values of 3.0, 7.0, and 9.0 are recommended as a suitable range to determine pH effects. Use of buffers may be desirable in certain cases where a change in pH during adsorption is to be avoided.

6.2 In cases where nonvolatile solutes are to be measured it is not necessary to fill the reagent bottle to the bottom of the ground-glass stopper. If any doubt exists as to the volatility of the solute(s) completely filled reagent bottles should be used.

6.3 Isotherm testing is usually conducted at room temperature ($22 \pm 2^{\circ}$ C) although conditions can be varied experimentally if desired.

COMPOUND: 2,6-Dinitrotoluene



	■ pH= 5.4			pH=			pH=		
CARBON DOSE mg/l	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M	C_f	$C_o - C_f = X$	X/M
0	10.58								
2.5	9.80	0.780	312						
5	9.28	1.30	260						
10	8.00	2.58	258						
20	5.48	5.10	255						
25	4.50	6.08	243						
50	1.45	9.13	183						
60	0.89	9.69	162						
75	0.56	10.02	134						
100	0.38	10.20	102						
125	0.21	10.37	83						
150	0.14	10.44	70						

APPENDIX B

PUBLISHED SOLUBILITIES OF SELECTED COMPOUNDS

Compound	Solubility mg/l	Temp. °C	Reference
Acenaphthene	3.47	25	1
Acrolein	40g/100 ml H_2O	-	2
Acrylonitrile	73,500	20	1
	75,000	25	2
Benzene	1,800	25	1
Benzidine	400	12	1
	400	-	2
Carbon Tetrachloride	785	20	1
	797	-	2
Chlorobenzene	488	25	1
	490	20	2
1,2,4 Trichlorobenzene	30	-	3
Hexachlorobenzene	0.006	25	1
1,2 Dichloroethane	8,690	20	1
	8,300	25	2
1,1,1 Trichloroethane	480 - 4,400	20	1
	4,400	20	2
Hexachloroethane	50	22	1
1,1 Dichloroethane	5,500	20	1
	5,000	-	2
1,1,2 Trichloroethane	4,500	20	1

Compound	Solubility mg/l	Temp. °C	Reference
1,2 Dichloropropane	2,700	20	1
	2,700	20	2
1,3 Dichloropropylene	(cis) 2,700	25	1
	(trans) 2.800	25	1
2,4 Dimethylphenol	17,000	160	1
3,5 Dimethylphenol	4,200	20	1
2,4 Dinitrotoluene	270	22	1
	300	22	2
2,6 Dinitrotoluene	no data		
1,2 Diphenylhydrazine	221	-	2
Ethylbenzene	152	20	1
	100	15	2
Fluoranthene	0.26	25	1
4 Chlorophenyl phenyl ether	59	20	1
4 Bromophenyl phenyl ether	38	20	1
Bis(2-chloroisopropyl) ether	1,700	-	1
Bis(2-chloroethoxy) methane	81,000	-	1
Methylene chloride	13,200 - 20,000	25	1
	20,000	20	2
Methyl chloride	6,450 - 7,250	20	1
	280 ml/100 ml H_2O	16	2
	5,380	25	7
Methyl bromide	900	20	1
	17,500	20	2
Bromoform	3,190	30	1
	1,300	25	2
Dichlorobromomethane	Insoluble	-	2
Trichlorofluoromethane	1,100	25	1
Dichlorodifluoromethane	280	25	1

Compound	Solubility mg/l	Temp. °C	Reference
1,1,2,2 Tetrachloroethane	2,900	20	1
	2,870	25	2
Chloroethane	5,740	20	1
	5,740	25	2
Bis(chloromethyl) ether	22,000(calculated)		1
	Hydrolyzes ($t_{1/2}$ = 38 sec)		1
	Decomposes		2
Bis(2-chloroethyl) ether	10,200	-	1
	11,000	20	2
2 Chloroethyl vinyl ether	15,000	-	1
2 Chloronaphthalene	6.74	25	1
2,4,6 Trichlorophenol	800	25	1
	900	25	2
Parachlorometacresol	3,850	20	1
	3,800	20	2
Chloroform	8,200	20	1
	8,200	20	2
2 Chlorophenol	28,500	20	1
	28,500	20	2
1,2 Dichlorobenzene	145	25	1
	145	25	2
1,3 Dichlorobenzene	123	-	1
	39	-	2
1,4 Dichlorobenzene	79	25	1
	80	25	2
3,3' Dichlorobenzidine	No data		
1,1 Dichloroethylene	400	20	1
	5,000	20	2
1,2 trans-Dichloroethylene	600	20	1
2,4 Dichlorophenol	4,500	20	1
	4,500	20	2

Compound	Solubility mg/l	Temp. °C	Reference
Chlorodibromomethane	No data		
Hexachlorobutadiene	2	20	1
Hexachlorocyclopentadiene	0.805	-	1
Isophorone	Insoluble	-	2
Naphthalene	34.4	25	1
	30	25	2
Nitrobenzene	1,900	20	1
	2,000	25	2
2 Nitrophenol	2,100	20	1
4 Nitrophenol	16,000	25	1
2,4 Dinitrophenol	5,600	18	1
	1,370	54.5	2
4,6 Dinitro-o-cresol	250	-	2
N-Nitrosodimethylamine	Miscible	-	1
N-Nitrosodiphenylamine	No data		
N-Nitrosodi-n-propylamine	9,895	25	1
Pentachlorophenol	14	20	1
	20	30	2
Phenol	93,000	25	1
	6700 mg/100 ml H_2O	25	2
Bis(2-Ethylhexyl)phthalate	50	25	1
Butyl benzyl phthalate	Insoluble	-	1
Di-n-butyl phthalate	4,500	25	1
	4,500	25	8
Di-n-octyl phthalate	Insoluble	-	1
Diethyl phthalate	1,000	32	1
Dimethyl phthalate	4,000	32	1

Compound	Solubility mg/l	Temp. °C	Reference
Benzo(a)anthracene	0.014	25	1
Benzo(a)pyrene	0.0038	25	1
3,4 Benzofluoranthene	0.0012	25	1
Benzo(k)fluoranthene	0.00055	25	1
Chrysene	0.002	25	1
Acenaphthylene	3.93	25	1
Anthracene	0.073 0.075	25 15	1 2
Benzo(ghi)perylene	0.00026	25	1
Fluorene	1.98	25	1
Phenanthrene	1.29 1.6	25 15	1 2
Dibenzo(a,h)anthracene	0.0005	25	1
Indeno(1,2,3-cd)pyrene	0.62	25	1
Pyrene	0.14	25	1
Tetrachloroethylene	150 - 200 200	20 -	1 2
Toluene	535 500	25 16	1 2
Trichloroethylene	1,100 1,000	20 25	1 2
Vinyl chloride	1.1 1	25 25	1 2
Aldrin	0.2	20	2
Dieldrin	0.186	25-29	2
Chlordane	0.056 1.85		3 4

Compound	Solubility mg/l	Temp. °C	Reference
4,4' DDT	0.002	-	2
4,4' DDE	0.010	-	3
	0.014	-	4
4,4' DDD	0.005	-	3
	0.020	-	4
a-Endosulfan-Alpha	0.530	-	4
b-Endosulfan-Beta	0.280	-	4
Endosulfan Sulfate	No data		
Endrin	0.23	25	2
Endrin aldehyde	No data		
Heptachlor	0.056	25-29	2
Heptachlor epoxide	0.350	-	4
	0.350	30	5
α BHC - Alpha	2.0	-	4
	2.03	28	6
β BHC - Beta	0.240	-	4
	0.20	28	6
γ BHC - Gamma	7.3	25	2
	31.4	-	4
	15.7	28	6
δ BHC - Delta		No data	6
PCB - 1242	0.24	-	1
	0.70	-	9
PCB - 1254	0.012	-	1
	0.07	-	9
PCB - 1221	15	-	1
	3.5	-	9
PCB - 1232	1.45	-	1
PCB - 1248	0.054	-	1

Compound	Solubility mg/l	Temp. °C	Reference
PCB - 1260	0.0027		1
	0.00095	-	7
PCB - 1016	0.34	-	1
	0.91	-	9
Toxaphene	3	20	2
2,3,7,8 Tetrachlorodibenzo-p-dioxin		No data	

References

1. Water-Related Environmental Fate of 129 Priority Pollutants. A Literature Search by Versar, Incorporated for USEPA Office of Water Planning and Standards. Contract No. 68-01-3852. January - February, 1979. Draft Copies.

2. ISHOW Data Base, University of Minnesota, Duluth. April 1979.

3. Spencer, W. F., and W. J. Farmer, Assessment of the Vapor Behavior of Toxic Organic Chemicals. Contribution of Federal Research, SEA, USDA, and the University of California, Riverside, California.

4. Weil, L., G. Dure, and K. E. Quentin, Solubility in Water of Insecticide Chlorinated Hydrocarbons and Polychlorinated Biphenyls in View of Water Pollution, Z. Wasser Abwasser Forsch. 7(6), 169 (1974.

5. Park, K. S., and W. N. Bruce, The Determination of the Water Solubility of Aldrin, Dieldrin, Heptachlor, and Heptachlor Epoxide. J. Econ. Entomol., 61, 770 (1968).

6. Kurihara, N., M. Uchida, T. Fujita, and M. Nakajima, Benzene Hexachloride Isomers and Related Compounds. Pestic. Biochem. Physio., 2(4), 383 (1973).

7. Chiou, C. T., V. H. Freed, D. W. Schmedding, and R. L. Kohnert, Partition Coefficient and Bioaccumulation of Selected Organic Chemicals. Environ. Sci. & Technol., 11(5) 475 (1977).

8. Residue Reviews, F. A. Gunther (editors), Springer-Verlag, New York, New York. 1975, p. 6.

9. Lee, M., E. Chian, and R. Griffin, Qualitative Study of the Solubility of Polychloroinated Biphenyls (PCBs) and Capacitor Fluid in Water. Progress Report for USEPA Grant R-804684 (October 1978).